

Physico-Theology
PHYSICO-THEOLOGY:

OR, A

DEMONSTRATION

OF THE

BEING and ATTRIBUTES of GOD,

FROM HIS

WORKS of CREATION.

Being the SUBSTANCE of

SIXTEEN SERMONS,

Preached in St Mary-le-Bow Church, London;

At the Honourable Mr *BOYLE*'s LECTURES, in
the Years 1711, and 1712.

With large NOTES, and many curious OBSERVATIONS.

By W. DERHAM, D. D. late Canon of Windsor,
Rector of Upminster in Essex, and F. R. S.

*Mala et impia consuetudo est contra Deos disputare, sine animo id
fit, sine simulate. Cic. de Nat. Deor. L. 2. fine.*

A NEW EDITION.

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PHYSIOLOGICAL

DEMONSTRATION

OF THE

WORKS AND ATTRIBUTES OF GOD

IN THE

WORKS OF HIS HANDS

SIXTH EDITION



A NEW EDITION

REVISED BY

JOHN G. ...

AND ...

...

TO THE

Most Reverend Father in GOD,

T H O M A S,

Lord Archbishop of CANTERBURY,
Primate of all *ENGLAND*, etc.

The Surviving TRUSTEE of the honour-
able Mr *BOYLE*'S LECTURES.

May it please your GRACE,

I MAY justly put these LECTURES under your Grace's patronage, their publication being wholly owing to you: for having the honour to be a member of the Royal Society, as well as a divine, I was minded to try what I could do towards the improvement of philosophical matters to theological uses; and accordingly laid a scheme of what I have here published a part of; and when I had little else to do, I drew up what I had to say, making it rather the diverting exercises of my leisure hours than more

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serious theological studies. This work, (although I made a considerable progress in it at first, whilst a novelty, yet) having no thoughts of publishing, I laid aside, until your Grace, being informed of my design by some of my learned friends, both of the clergy and laity, was pleased to call me to the unexpected honour of preaching Mr Boyle's Lectures: an honour I was little aware of in my country-privacy, and not much acquainted with persons in high stations, and not at all, particularly, with your Grace. So that therefore as it pleased your Grace, not only to confer an unsought profitable honour upon me, a stranger, but also to continue it for two years, out of your good opinion of my performance, in some measure, answering Mr Boyle's end; so I can do no less than make this public, grateful acknowledgement of your Grace's great and unexpected favour.

BUT it is not myself alone; but the whole Lecture also is beholden to your Grace's kind and pious endeavours. It was you that encouraged this noble cha-

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riety, and assisted in the settlement of it, in the honourable founder's lifetime; and since his death, it was you that procured a more certain salary for the Lectures, paid more constantly and duly than it was before *.

THESE benefits, as I myself have been a sharer of, so I should be very ungrateful, should I not duly acknowledge, and repay with my repeated thanks and good

* It may not only gratify the reader's curiosity, but also be of use for preventing encroachments in time to come, to give the following account of Mr Boyle's Lectures.

Mr Boyle, by a codicil, dated July the 28th, 1691, and annexed to his will, charged his messuage or dwelling-house, in St Michael's Crooked Lane, London, with the payment of the clear yearly rents and profits thereof, to some learned divine in London, or with the Bills of mortality, to be elected for a term not exceeding three years, by his grace the present lord archbishop of Canterbury, then Dr Tenison, Sir Henry Ashurst, Sir John Rotheram, and John Evelyn, Esq; The business he appointed those lectures for, was, among others, 'To be ready to satisfy real scruples, and to answer such new objections and difficulties, as might be started, to which good answers had not been made.' And also, 'To preach eight sermons in the year, viz. the first Monday of January, February, March, April, and May; and of September, October, and November.' The subject of these sermons was to be, 'The proof of the Christian religion against notorious infidels, viz. Atheists, Theists, Pagans, Jews, and Mahometans; not descending lower to any controversies that are among Christians themselves.' But by reason the lecturers were seldom continued above a year, and that the house sometimes stood empty, and tenants brake, or failed in due payment of their rent, therefore the salary sometimes remained long unpaid, or could not be gotten without some difficulty: to remedy which inconvenience, his present grace of Canterbury procured a yearly stipend of 50 l. to be paid quarterly for ever, charged upon a farm in the parish of Brill, in the county of Bucks: which stipend is accordingly very duly paid, when demanded, without fee or reward.

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wishes. And that the infinite Rewarder of well-doing, may give your Grace a plentiful reward of these, and your many other, both public and private benefactions, is the hearty wish of

Your GRACE'S

Most humble and thankful

Son and servant,

W. DERHAM.

TO THE
R E A D E R.

AS the noble founder of the Lectures I have had the honour of preaching, was a great improver of natural knowledge, so, in all probability, he did it out of a pious end, as well as in pursuit of his genius. For it was his settled opinion, that nothing tended more to cultivate true religion and piety in a man's mind, than a thorough skill in philosophy. And such effect it manifestly had in him, as is evident from divers of his published pieces; from his constant deportment, in never mentioning the name of God without a pause, and visible stop in his discourse; and from the noble foundation of his lectures for the honour of God, and the generous stipend he allowed for the same.

Vid. bp. Burnet's funeral sermon, p. 24.

AND forasmuch as his lectures were appointed by him for the proof of the Christian religion, against Atheists, and other notorious infidels, I thought, when I had the honour to be made his lecturer, that I could not better come up to his intent, than to attempt a demonstration of the being and attributes of God, in what I may call Mr Boyle's own, that is, a physico-theological way. And, besides that, as it was for this very service that I was called to this honour, I was the more induced to follow this method, by reason none of my learned and ingenious predecessors in these lectures, have done it on purpose, but only casually, in a transient, piece-meal manner; they having made it their business to prove the great points of Christianity in another way, which they have accordingly admirably done. But considering what our honourable founder's opinion was of natural knowledge, and that his intent was, that those matters, by passing through divers hands, and by being treated of in different methods, should take in most of what could

Vid. Mr Boyle's will.

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be said upon the subject; I hope my performance may be acceptable, although one of the meanest.

AS for others, who have before me done something of this kind; as Mersenne, on Genesis; Dr Cockburn, in his Essays; Mr Ray, in his Wisdom of God, &c.; and I may add the first of Mr Boyle's lecturers, the most learned Dr Bentley, in his Boyle's lectures, the eloquent archbishop of Cambray, (and, I hear, the ingenious Monsieur Perault hath something of this kind, but never saw it): I say, as to these learned and ingenious authors, as the creation is an ample subject, so I industriously endeavoured to avoid doing over again what they before had done; and for that reason did not, for many years, read their books, until I had finished my own. But when I came to compare what each of us had done, I found myself in many things to have been anticipated by some or other of them, especially by my friend, the late great Mr Ray. And therefore in some places I shortened my discourse, and referred to them; and in a few others, where the thread of my discourse would have been interrupted, I have made use of their authority, as the best judges; as of Mr Ray's, for instance, with relation to the mountains, and their plants, and other products. If then the reader should meet with any thing mentioned before by others, and not accordingly acknowledged by me, I hope he will candidly think me no plagiarist, because I can assure him I have all along, where I was aware of it, cited my authors, with their due praise. And it is scarce possible, when men write on the same, or a subject near a-kin, and the observations are obvious, but that they must often hit upon the same thing: and frequently this may happen from persons making observations about one, and the same thing, without knowing what each other hath done; which indeed, when the first edition of my book was nearly printed off, I found to be my own case, having (for want of Dr Hook's Micrographia being at hand, it being a very scarce book, and many years since I read it), given descriptions of two or three things, which I thought had not been tolerably well observed before, but are described well by that curious gentleman.

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ONE is a feather, the mechanism of which we in the main agree in, except in his representation in fig. 1. scheme 22. which is somewhat different from what I have represented in my fig. 18, &c. But I can stand by the truth, though not the elegance of my figures. But as to the other differences, they are accidental, occasioned by our taking the parts in a different view, or in a different part of a vane; and to say the truth, (not flattering myself, or detracting from the admirable observations of that great man), I have hit upon a few things that escaped him, being enabled to do so, not only by the help of such microscopes as he made use of; but also by those made by Mr Wilson, which exceed all I ever saw, whether of English, Dutch, or Italian make; several of which sorts I have seen and examined.

THE other thing we have both of us figured and described is, the sting of a bee or wasp; in which we differ more than in the last. But by a careful re-examination, I find, that although Dr Hook's observations are more critical than any were before, yet they are not so true as mine. For as to the scabbard, as he calls it, I could never discover any beards thereon; and I dare be confident there are none, but what are on the two spears. And as to the point of the scabbard, he hath represented it as tubular, or bluntish at the top; but it really terminates in a sharp point, and the two spears and the poison come out of a slit, or longish hole, a little below the top or point. And as to the spears, he makes them to be but one, and that the point thereof lies always out of the scabbard. But by a strict examination, they will be found to be two, as I have said, and that they always lie within the scabbard, except in stinging; as I have represented them in fig. 21. from the transparent sting of a wasp. And as to the spear being made of joints, and parted into two, as his fig. 2. scheme 16. represents I could never upon a review discover it to be so, but imagine, that by seeing the beards lying upon, or behind the spears, he might take them for joints, and by seeing the point of one spear lie before the other, he

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might think the spear was parted in two. But lest the reader should think himself imposed upon by Dr Hook, and myself, it is necessary to be observed, that the beards, or tenterhooks, as Dr Hook calls them, lie only on one side of each spear, not all round them: and are therefore not to be seen, unless they are laid in a due posture in the microscope, viz. sideways, not under, or a-top the spear.

THE last thing, which scarce deserves mention, is the mechanism of the hair, which Dr Hook found to be solid, like a long piece of horn, not hollow, as Malpighi found it in some animals. And I have found both those great men to be in some measure in the right, the hair of some animals, or in some parts of the body, being very little, if at all tubular: and in others, particularly mice, rats, and cats, to be as I have represented in my fig. 14, &c.

AND now, if my inadvertency in other things hath no worse effect than it hath had in these, namely, to confirm, correct, or clear others observations, I hope the reader will excuse it, if he meets with any more of the like kind. But not being conscious of any such thing, although probably there may be many such, I am more solicitous to beg the reader's candour and favour, with relation both to the text and notes: in the former of which, I fear he will think I have as much under-done, as in the latter over-done, the matter: but for my excuse, I desire it may be considered, that the textual part being sermons, to be delivered in the pulpit, it was necessary to insist but briefly upon many of the works of God, and to leave out many things that might have been admitted in a more free discourse. So that I wish it may not be thought I have said too much, rather than too little, for such an occasion and place. And indeed, I had no small trouble in expounding some things, altering many, and softening the most, and, in a word, giving, in some measure, the whole, a different dress than what I had at first drawn it up in, and what it now appears in.

AND as for the notes, which may be thought too

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large, I confess I might have shortened them, and had thoughts of doing it, by casting some of them into the text, as an ingenious learned friend advised. But when I began to do this, I found it was in a manner to new-make all, and that I should be necessitated to transcribe the greatest part of the book, which, having no assistant, would have been too tedious for me, being pretty well fatigued with it before. I then thought it best to pare off from some, and to leave out others; and accordingly did so in many places, and would have done it in more, particularly, in many of the citations out of the ancients, both poets and others, as also in many of the anatomical observations, and many of my own and others observations: but then I considered, as to the first, that those citations do, many of them at least, shew the sense of mankind about God's works, and that the most of them may be acceptable to young gentlemen at the universities, for whose service these lectures are greatly intended. And as to the anatomical notes, and some others of the like nature, most of them serve either to the confirmation, or the illustration, or explication of the text, if not to the learned, yet to the unskilful, less learned reader; for whose sake, if I had added more, I believe he would forgive me. And lastly, as to the observations of myself, and some others, where it happens that they are long, it is commonly where a necessity lay upon me of fully expressing the author's sense, or my own, or where the thing was new, and never before published; in which case, it was necessary to be more express and particular, than in matters better known, or where the author may be referred unto.

IN the former editions I promised another part I had relating to the heavens, if I was thereunto encouraged. And two large impressions of this book having been sold off, so as to admit of a third before the year was gone about; and hearing that it is translated into two, if not three languages; but especially being importuned by divers learned persons, both known and unknown, I have thought myself sufficiently enga-

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ged to perform that promise; and have accordingly published that part.

SO that I have now carried my survey through most parts of the visible creation, except the waters, which are for the most part omitted; and the vegetables, which, for want of time, I was forced to treat of in a perfunctory manner. And to the understanding of the former of these, having received divers solicitations from persons unknown, as well as known, I think myself bound in civility to own their favour, and to return them my hearty thanks for the kind opinion they have shewn of my other performances, that they have encouraged me to undertake this other task. And accordingly I have begun it, and, as far as my affairs will permit, have made some progress in it: but age and avocations growing upon me, I begin to fear I shall scarce be able to finish it as I would, and therefore must recommend that ample and noble subject to others, who have more leisure, and would do it better than I.

AS to additions, I have been much solicited thereunto by divers curious and learned persons, who would have had me to insert some of their observations, and many more of my own: but in a work of this nature, this would have been endless: and although the book would thereby be rendered much better, and more complete, yet I could by no means excuse so great an injustice to the purchasers of the former editions. And therefore, except in the second edition, where it was not easy to be avoided, few additions or alterations have been made, besides what were typographical, or of small consideration. Only in the third edition I amended the first paragraph of note 1. chap. 5. book 1. concerning gravity; and in the fourth, pag. 16, and 18, I inserted two passages out of Seneca, that were inadvertently left out, and corrected many things, that upon a careful review, seemed to want amendment.

AND lastly, as to the following analysis, it was added at the request of some of my learned and ingenious friends; and although it might have been contracted, they would not suffer it to be so.

A N

A N A L Y S I S

O F T H E

F O L L O W I N G B O O K.

TH E works of the creation relating to our terraqueous globe, are such as are visible in the

Outworks or appendages of the globe, viz. these three :

1. The atmosphere.

Composed of air and vapours, Page 36.

Useful to

{ Respiration and animal life, *ibid.*

{ Vegetation of plants, 40.

{ Conveyance of

{ { The winged tribe.

{ { Sound, 42.

{ The functions of nature.

{ Reflecting and refracting light, 43.

Containing the

{ Winds, which are of great use and necessity

{ { To the salubrity and pleasure of the air, 46.

{ { In various engines, 48.

{ In navigation.

{ Clouds and rain : of great use to the

{ { Refreshment of the earth and the things therein, 50.

{ { Origin of fountains, according to some, 54.

2. Light. Its

{ Fountain, 56.

{ { Wonderful necessity and use,

{ { Improvement by glasses, 57.

{ Velocity.

{ Expansion, 58.

3. Gravity.

- { Its great benefit, 61.
- { Cause of levity, which is of great use in the world, 63.
- { Terraqueous globe itself. Of which I take a view in
 - General, of
 - { Its spherical figure, which is the most commodious in regard of
 - { Light, 68.
 - { Heat.
 - { Lodgment of the waters.
 - { The winds, 69.
 - { Its bulk, 70.
 - { Its motion, *ibid.*
 - { Annual.
 - { Diurnal.
 - { Its place and distance from the sun, and other heavenly bodies, 73.
 - { Its distribution, so as to cause all the parts of the globe to
 - { Balance each other, 74.
 - { Be helpful to one another.
 - { The great variety and quantity of all things serving for food, physick, building, and every use and occasion of all ages, places, and creatures, 79.
 - { An objection answered, 80, 81.
 - Particular, of the earth; of its
 - Constituent parts, viz. Its
 - { Soils and moulds necessary to the
 - { Growth of various vegetables, 86.
 - { Various occasions of man and other animals, 87.
 - { Various strata or beds, affording materials for
 - { Tools.
 - { Firing.
 - { Building.
 - { Dying, and thousands of other things, 89.
 - { Conveyance of the sweet fountain-waters, 90.
 - { Subterraneous caverns and volcanos; of great use to the countries where they are, 92.
 - { Mountains and vallies, which are not rude ruins, but works of design, inasmuch as the structure of the earth is
 - { The most beautiful and pleasant.
 - { The most salubrious: to some constitutions, the hills; to some, the valleys, 96.
 - { Best to screen us, and other things, *ibid.*
 - { Beneficial to the
 - { Production of various vegetables.
 - { Harbour and maintenance of various animals, 97.
 - { Generation of minerals and metals, 99.
 - { Absolutely necessary to the conveyance of the rivers; and in all probability, to the origin of fountains, *ibid.*

Conclusion against blaming God, 105.

Its inhabitants; which are either sensitive or insensitive.

Concerning the

Sensitive, some things are

Common to all the tribes, particularly these ten:

I. The five senses and their organs; the, 108.

Eye, an admirable piece of mechanism in regard of its

Form for the most part spherical, which is best for

{ The reception of objects.

{ Motion of the eye, 112.

Situation in the most commodious part of the body of every creature.

Motion, in some animals

{ Every way.

{ Fixed; and the excellent provision in that case, 113.

Size; which is in

{ All creatures, according to their occasions.

{ Such as live abroad in the light, larger.

{ Such as live under ground, less.

Number, in some animals

{ Two, 115.

{ More: together with the wise provision to prevent double vision.

Parts; some of which are viewed

{ Transiently, the arteries, veins, and some of the muscles and tunics.

{ More strictly, some of the

{ Muscles, and the excellent provision made for their peculiar uses, equilibration, etc. 118.

{ Tunics: among which the various apertures, forms, and positions of the pupil are particularly noted, 120.

{ Humours, especially the prodigious finery and composition of the crystalline, according to Mr Lewenhoeck.

{ Nerves, 126.

{ Optic.

{ Motory.

Guard and security provided for by

The reparation of the aqueous humour.

{ Covering the eye-lids.

{ Strong and curious bones.

{ Hard and firm tunics.

{ Withdrawing them into their heads, 130.

Of erect vision, 131.

Hearing. Its

Organ, the ear, 132.

{ Double, enabling us to hear every way, and a good provision for the loss or hurt of one.

{ Situated in the very best place for information, security, and near the eye and brain.

{ The fabric of the

{ Outward ear, which is in

{ All creatures formed, guarded, placed, and every way accounted according to their various places and occasions, 135.

{ Man suitable to his erect posture; and all its parts, the helix, tragus, concha, etc. admirably suited to the reception and melioration of sounds, and the security of the part.

{ Inward ear: in which I take a view of the, 140.

{ Auditory passage, curiously tunnelled, tortuous and smooth; and being always open, is lined with the nauseous ear-wax for a guard.

Tuba Eustachiana, 140.

{ Bone, particularly hard and context, for guard, and to assist the sound.

{ Tympanum, and its membrane, muscles, and four little bones, to correspond to all kinds of sound.

Labyrinth, semicircular canals, cochlea; all made with the utmost art, 145.

{ Auditory nerves, one of which is ramified to the eye, tongues, muscles of the ear, and to the heart; whence a great sympathy between those parts, 145.

Object, sound. Under which I consider,

{ The improvements thereof by the wit of man, 146.

{ Its great necessity, and excellent uses, 147.

{ Its pleasure, and the power of music, 150.

Smelling. In which sense these things are remarkable; the

{ Nostrils, always open, cartilaginous, and endowed with muscles, 153.

{ Laminae, serving for

{ A guard against noxious things, 154.

{ The spreading of the olfactory nerves.

{ Prodigious use of it in all, especially some of the irrational, 155.

Taste. The things most remarkable in which sense are, the

{ Nerves spread about the tongue and mouth, with their guard.

{ The papillae neatly made, 156.

- | Situation thereof to be a centinel to the stomach and food.
 - | Consent thereof with the other senses, by some branches of the fifth pair, 157.
 - | Feeling, 158.
 - { Whose organ is the nerves, *ibid.*
 - { Which is dispersed through every part of the body, and the admirable benefit thereof.
- II. Respiration the grand act of animal life, 160.
 - { Ministering to the circulation of the blood and diastole of the heart.
 - The parts concerned therein are,
 - { The larynx, with its great variety of muscles, etc. for respiration, and forming the voice, 163.
 - { Trachea and epiglottis, exquisitely contrived and made.
 - { Bronchi and lungs, with their curious arteries, veins, and nerves, 165.
 - { Ribs, diaphragm, and the several muscles concerned.
 - Its defects in the
 - { Foetus in the womb, 167.
 - { Amphibious creatures, 170.
 - { Some animals in winter.
- III. The motion of animals: concerning which I consider
 - Transiently the
 - { Muscles, and their structure, their size, fastening to the joints, motions, etc. 172.
 - { Bones, and their curious make.
 - { Joints, with their form, bandage, and lubricity, 174.
 - { Nerves, and their origin, ramifications, and inosculation.
 - More particularly the loco-motive act itself, which is
 - { Swift or slow, with wings, legs many or few, or none at all, according to the various occasions and ways of animals lives. As particularly in
 - { Reptiles, whose food and habitation is near at hand.
 - { Man and quadrupeds; whose occasions require a larger range, and therefore a swifter motion, 176.
 - { Birds, and insects, whose food, habitation, and safety require yet a larger range, and have accordingly a yet swifter motion and direct conveyance.
 - Geometrically and neatly performed by the nicest rules. Well provided for by the
 - { Due equipoise of the body, 178.
 - { Motive parts being accurately placed with regard to the centre of the body's gravity, and to undergo their due proportion of weight and exercise.

- IV. The place allotted to the several tribes of animals to live and act in. Concerning which I observe, that
- { Their organs are adapted to their place, 179.
 - { All places habitable are duly stocked.
 - { Various animals have their various places; and the wisdom thereof, 180.
- V. The balance of animals numbers, so that the world is not
- { Overstocked by their increase.
 - { Depopulated by their death.
- Which is effected in.
- { The several tribes of animals by a due proportion in the
 - { Length of their life, 181.
 - { Number of their young, in
 - { Useful creatures being many.
 - { Pernicious few.
 - { Man very remarkable, by the
 - { Different lengths of his life.
 - { Soon after the creation, 183.
 - { When the world was more, but not fully peopled, ibid.
 - { When it was sufficiently stocked, down to the present time.
 - { Due proportions of marriages, births, and burials, 185.
 - { Balance of males and females, 186.
- VI. The food of animals. In which the divine management and providence appears, in the, 191.
- { Maintaining such large numbers of all kinds of animals on land, in the seas, and divers places too unlikely to afford sufficient food.
 - { Adjustment of the quantity of food to the number of devourers, so that
 - { There is not too much, so as to rot, and annoy the world, 192.
 - { The most useful is the most plentiful, and easiest propagated, ibid.
 - { Delight which the various tribes of animals have to the varieties of food, so that what is grateful to one, is nauseous to another: which is a wise means to cause
 - { All creatures to be sufficiently supplied.
 - { All sorts of food to be consumed.
 - { The world to be kept sweet and clean by those means, 194.
 - { Peculiar food, that particular places afford to the creatures residing therein, ibid.
 - { Curious apparatus in all animals for gathering, and digestion of their food, viz. the

Mouth, nicely shaped for food; etc. In

Some little and narrow, 199.

Some, with a large deep incisure.

Insects very notable to catch, hold, and devour prey; to carry burdens, to bore and build their habitations, 200.

Birds as notable, horned in all. In some

Hooked for rapine, climbing, etc. 201.

Sharp and strong to pierce trees, etc.

Long and slender to grope.

Long and broad to quaffer.

Thick and sharp-edged to husk grain.

Compressed to raise limpets, etc.

Teeth, which are peculiarly hard, firmly inserted in the jaws, variously shaped in the same and different animals, deficient in young creatures, etc. 203.

Salival glands, commodiously placed for mastication and deglutition, 205.

Muscles and tendons, serving to mastication, strong and well lodged.

Gullet, sized according to the food; with curious fibres, etc. *ibid.*

Stomach; 206.

Which hath a curious mechanism of fibres, tunics, glands, nerves, arteries, and veins.

Whose faculty of digestion by such seeming weak menstrua is admirable.

Whose size and strength is conformable to the nature of the food, or occasions of animals.

Which is in

Some tame animals but one.

Some ruminants, birds, etc. more.

Guts, whose tunics, glands, fibres, valves, and peristaltic motion, deserve admiration, 209.

Lacteals, together with the impregnations from the pancreas, gall, glands, and lymphæducts.

Sagacity of all animals in finding out, and providing food. In

Man less remarkable for the sake of his understanding, 210.

Inferior creatures. In such as are

Come to mature age, and are able to help themselves by their

Accurate smell, 211.

Natural craft.

Hunting and groping out of sight.

Seeing and smelling at great distances, 213.

Climbing; the strong tendons and muscles acting therein.

Seeing in the dark.

Helpless. As, 214.

Young creatures.

Man, born the most helpless of any, the parents reason, hands, and affection sufficing.

Irrationals: for whose young the Creator hath made a sufficient provision, partly by the

Parent-animals own

Strepsh, and diligence in nursing and defending them, 215.

Sagacity and care in repositing their eggs and young, where food and all necessaries are to be found, 216.

Ability of the young themselves to shift for, and help themselves, with the little helps of their dams, 217.

Creatures destitute of food at some seasons, or likely to want it, who

Are able to live long without food, 218.

Lay up food before-hand.

VII. The clothing of animals, which is, 221.

Suited to the place and occasions of all. In

Man it is left to his own reason and art, joined with sufficient materials: which is best for him,

Because he may suit his clothing to his quality and business, 225.

For perspiration and health sake.

To exercise his art and industry.

To excite his diligence in keeping himself sweet and clean.

In being the parent of divers callings, *ibid*.

Irrationals: who are either

Ready furnished with proper cloathing,

On the dry land with hair, fleeces, furs, shells, hard skins. etc. 226.

In the air with feathers, light, strong, and warm.

In the waters with scales, hard for guard; smooth for passage; or with strong shells to guard such as move more slowly, 229.

Provide for themselves by their textrine, or architectonic art. Of which under the next branch.

Well garnished, being all workman-like, complete, in its kind beautiful, being, *ibid*.

Adorned with gay, various, and elegant colours.

If sordid, yet with exact symmetry, and full of curious mechanism,

VIII. The houses and habitations of

Man, who is abundantly furnished with

{ Contrivance and art to build and garnish his habitations, 231.

{ Materials of all sorts to effect his works.

Irrationals, whose marvellous instinct is manifested by the Convenience of their nests and habitations for the

{ Hatching and education of their young, 232.

{ Guard and defence of themselves and their young.

{ Fabric of their nests, scarce imitable by man, and shewn by their contrivance and make, being exactly suitable to their occasions, and made by

{ Putting only a few ugly sticks, moss, dirt, etc. together, 235.

{ Building combs according to the best rules of mathematics.

{ Weaving webs, and making cases. For which service the parts of their bodies, and materials afforded by them, are very considerable.

IX. Animals self-preservation. For which there is always a guard in proportion to the dangers and occasions of their state. Which is observable in

{ Man, whose reason and art supplies the defect of natural armature.

{ Irrational creatures: who

{ As they are on one hand sufficiently guarded by their

{ Shells, horns, claws, stings, 242.

{ Changing their colours.

{ Wings, feet, and swiftness.

{ Diving in, and tinging the waters.

{ Ejecting juices out of their body.

{ Accurate smell, sight, and hearing.

{ Natural craft, 246.

{ Uncouth noise, ugly gesticulations, and horrid aspect.

{ Horrible stink and excrements.

{ So on the other hand can by their strength, sagacity, or natural artifices, entrap and captivate what is necessary for their food and other occasions.

X. Animals generation.

{ Equivocal, is denied, 246

{ Univocal: which of

{ Man, is *equivocal*, *is*, passed wholly by.

{ Irrational creatures, which is remarkable for their sagacity in chusing the fittest place for their eggs and young: where it is observable what a

- { Complete order they observe.
- { Neat apparatus their bodies are provided with for this purpose, 249.
- { Natural venom they inject with their eggs into vegetables to pervert nature, and produce balls, and cates, 252.

Making use of the fittest seasons, either

- { All seasons, *ibid.*
- { When provisions are most plentiful, and easiest had.
- { Due number of young, 253.
- { Diligence and concern for their young, in point of Incubation, 254.
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- { Suckling them. In which it is observable
- { How suitable this food is.
- { How willingly parted with by all, even the most savage.
- { What a complete apparatus in all creatures of dugs, etc.
- { Putting food in their mouths, with their proper parts for catching and conveying food, 256.
- { Neither way, but by laying in provisions beforehand, 257.

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Man; whom I consider with relation to his

Soul. Concerning which, having cursorily mentioned divers things, I insist upon two, as shewing an especial divine management, the

- { Various genii, or inclinations of men, which is a wise provision for the dispatch of all the world's affairs, and that they may be performed with pleasure, 262.
- { Inventive faculty. In which it is remarkable that

{ Its compass is so large, extending to all things of use, and occasioning so many several callings.

{ Things of greatest necessity and use were soon and easily found out; but things less useful later, and dangerous things not yet. Here of divers particular inventions, with an exhortation to exercise and improve our gifts.

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{ Erect posture, 279.

{ The most convenient for a rational being.

{ Manifestly intended, as appears from the structure of some particular parts mentioned, 281.

{ Nice structure of the parts ministering thereto.

{ Equilibration of all the parts, 283.

Figure and shape of man's body most agreeable to his place and business, 283.

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Structure of the parts, which are

- { Without botches and blunders.
- { Of due strength.
- { Of the best form.
- { Most accurately accommodated to their proper offices.

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- { Five senses, 291.
- { Hands.
- { Legs and feet.
- { Heart.
- { Viscera.
- { Several bones and muscles, etc. 293.
- { Covering of all with the skin.

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- { Situation of the eyes, ears, tongue, and hand, 294.
- { Guard afforded all, especially the principal parts.
- { Duplication of some parts.

Cure of evils by means of

- { Proper emunctories, 295.
- { Diseases themselves making discharges of things more dangerous, *ibid.*
- { Pain giving warning, and exciting our endeavours.

Content of the parts, effected, by the nerves, a sample whereof is given in the fifth pair, branched to the eye, ear, etc.

Political, sociable state. For the preservation and security of which the Creator hath taken care by variety of means

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 - { Strength and slow motion, 306,
 - { Agility and swiftneſs.
 - { Walking and running.
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- Traversing the plains.
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- Its usefulness to
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- Answering to the length of the legs, 312.
- Strengthened by the white-leather.
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- Body and motion; where I consider
 - The parts concerned in their motion, 321.
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 - Most exactly made for lightness and strength.
 - All well placed in every part, for the covering and motion of the body.
 - Preened and dressed, 322.
 - Wings, which are
 - Made of the very best materials, viz. of bones

light and strong; Joints exactly opening, shutting, and moving, as the occasions of flight require; and the pectoral muscles, of the greatest strength of any in the whole body.

Placed in the nicest point of the body of every species, according to the occasions of flight, swimming, or diving.

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{ Performed by the nicest laws of mechanics.

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{ Head, remarkable for the commodious

{ Shape of itself, 327.

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{ Macerate and prepare, 331.

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 - { Their times of passage, 334.
 - { The places proper for them.
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 - { The egg, and its parts, 336.
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 - { Eyes, reticulated to see all ways at once, 345.
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 - { Creeping, 346.
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 - { Wings, which are
 - { Nicely distended with bones, 349.
 - { Some incomparably adorned with feathers and elegant colours.
 - { Some jointed and folded up in their elytra, and distended again at pleasure.
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- Security against winter, by their
 - { Subsisting in a different, viz. their nympha or aurelia-state, 352.
 - { Living in torpitude, without any waste of body or spirits, 353.
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A

S U R V E Y

OF THE

TERRAQUEOUS GLOBE.

I N T R O D U C T I O N.

IN Psal. cxi. 2. the psalmist asserts, that ‘ the
‘ (a) works of the Lord are great; sought out
‘ of all them that have pleasure therein.’

This is true of all God’s works, particularly of his works of creation: which when sought out; or as the Hebrew word (b) signifieth, when heedfully and deeply pried into, solicitously observed and inquired out, especially when clearly discovered to us; in this case, I say, we find those works of God abundantly to deserve the psalmist’s character of being great and

(a) It is not unlikely that the psalmist might mean, at least have an eye to, the works of creation in this text, the word מַעֲשֵׂה being the same that in Psal. xix. 1. is translated God’s handy-work, which is manifestly applied to the works of creation, and properly signifieth, ‘ factum, opus, officium,’ from מַעַשׂ ‘ fecit, paravit, aptavit.’ And, saith Kircher, ‘ Significat talem affectionem qua aliquid existit vel realiter, vel ornate, vel ut non sit in pristino statu quo fuit.’ Concord, p. 2. col. 931.

(b) מְרַשֵּׁשׁ ‘ Quæsit, perquisivit, sciscitatus est’ Buxtor. in ver. ‘ Et simul importat curam, et sollicitudinem.’ Conrad. Kircher. lib. p. 1. col. 1174.

noble; inasmuch as they are made with the most exquisite art, (c) contrived with the utmost sagacity, and ordered with a plain wise design, and ministering to admirable ends (d). For which reason St Paul might well affirm of those Ποιήματα of God, that the
 ‘invisible things of God, even his eternal power and
 ‘Godhead, are understood by them.’ And indeed they are the most easy and intelligible demonstrations of the being and attributes of God; (e) especially to such as are unacquainted with the subtilties of reasoning and argumentation; as the greatest part of mankind are.

It may not therefore be unsuitable to the nature

(c) ‘Quod si omnes mundi partes ita constitutae sunt, ut neque ad usum meliores potuerint esse, neque ad speciem pulchriores; vedeamus utrum ea fortuita sint, an eo statu, quo cohaerere nullo modo potuerint, nisi sensu moderante divinaque providentia. Si ergo meliora sunt ea quae natura, quam illa, quae arte perfecta sunt, nec ars efficit quid sine ratione; ne natura quidem rationis expertis est habenda. Qui igitur convenit, signum, aut tabulam pictam cum adspexeris, scire adhibitam esse artem; cumque procul cursum navigii videris, non dubitare, quin id ratione atque arte moveatur: aut cum solarium, etc. mundum autem, qui et has ipsas artes, et earum artifices, et cuncta complectatur, consilii et rationis esse expertem putare? quod si in Scythiam, aut in Britanniam, sphaeram aliquis tulerit hanc, quam nuper familiaris noster effecit Posidonius, cujus singulae conversiones idem efficiunt in sole, etc.—quod efficitur in coelo singulis diebus et noctibus; quis in illa barbarie dubitet, quin ea sphaera sit perfecta ratione? hi autem dubitant de mundo, ex quo et oriuntur, et fiunt omnia, casu ne ipse sit effectus,—an ratione, an mente divina? et Archimedem arbitrantur plus valuisse in imitandis sphaerae conversionibus, quam naturam in efficiendis, praesertim cum multis partibus sint illa perfecta, quam haec simulata, solertius, etc.’ Cic. de Nat. l. 2. c. 34. 35.

(d) And a little before he saith of nature itself, ‘Omnem ergo regit naturam ipse [Deus], etc.’

(e) ‘Mundus codex est Dei, in quo jugiter legere debemus.’ Bernard. Serm.

‘Arbitror nullam gentem, neque hominum societatem, apud quos ulla Deorum est religio, quidquam habere sacras Eleusiniis aut Samothraciis simile: ea tamen obscure docent quae profitentur: naturae vero opera in omnibus animantibus sunt perspicua.’ Galen de Us. Part. l. 17. c. 1.

and design of lectures (*f*), founded by one of the greatest virtuosos of the last age, and instituted too on purpose for the proof of the Christian religion against atheists, and other infidels, to improve this occasion in the demonstration of the being and attributes of an infinitely wise and powerful Creator, from a cursory survey of the works of creation, or, as often called, of nature.

Which works belong either to our terraqueous globe, or the heavens.

I shall begin with our own globe, being nearest, and falling most under our senses. Which being a subject very various and copious, for the more methodical and orderly proceeding upon it, I shall distribute the works therein,

I. Into such as are not properly parts, but appendages or out-works of the globe.

II. The globe itself.

(*f*) 'Philosophia est catechismus ad fidem.' Cyril. 1. contr. Jul.

B O O K I.

*Of the Out-works of the Terraqueous Globe;
the Atmosphere, Light, and Gravity.*

C H A P. I.

Of the Atmosphere in general.

THE atmosphere, or mass of air, vapours and clouds, which surrounds our globe, will appear to be a matter of design, and the infinitely wise Creator's work, if we consider its nature and make (a), and its use to the world (b).

1. Its nature and make, a mass of air, of subtile penetrating matter, fit to pervade other bodies, to penetrate into the inmost recesses of nature, to excite, animate, and spiritualize; and, in short, to be the very soul of this lower world. A thing consequently,

2. Of greatest use to the world, useful to the life, the health, the comfort, the pleasure, and business of the whole globe. It is the air the whole animal world breatheth, and liveth by; not only the animals inhabiting the earth (c) and

(a) 'Mundi pars est aer et quidem necessaria: hic est enim qui coelum terramque connectit, etc.' Senec. Nat. Qu. l. 2.

c. 4.

(b) 'Ipse aer nobiscum videt, nobiscum audit, nobiscum sonat; nihil enim eorum sine eo fieri potest, etc.' Cic. de Nat. Deor. l. 2. c. 33.

(c) As the air is of absolute necessity to animal life, so it is necessary that it should be of a due temperament or consistence; not foul, by reason that suffocath; not too rare and thin, because that sufficeth not: with examples of each of which I shall a little entertain the reader. In one of Mr Hawksbee's compressing engines, I closely shut up a sparrow, without forcing any air in; and in less than an hour the bird began to pant, and be concerned; and in less than an hour and half to be sick, vomit, and more out of breath; and in two hours time was nearly expiring.

Another I put in and compressed the air, but the engine leaking, I frequently renewed the compressure; by which means, (although the bird panted a little after the first hour) yet after such frequent compressures, and immission of fresh air, it was very little concerned, and taken out seemingly unhurt after three hours.

After this I made two other experiments in compressed air; with the weight of two Atmospheres injected, the engine holding tight and well; the one with the great titmouse, the other with a sparrow. For near an hour they seemed but little concerned; but after that grew fainter, and in two hours time sick, and in three hours time died. Another thing I took notice of, was, that when the birds were sick, and very restless, I fancied they were somewhat relieved for a short space, with the motion of the air, caused by their fluttering and shaking their wings, (a thing worth trying in the diving bell). I shall leave the ingenious reader to judge what the cause was of both the birds living longer in compressed, than uncompressed air; whether a less quantity of air was not sooner fouled and rendered unfit for respiration, than a greater.

From these experiments two things are manifested; one is, that air, in some measure compressed, or rather heavy, is necessary to animal life: of which by and by. The other, that fresh air is also necessary; for pent up air, when overcharged with the vapours emitted out of the animal's body, becomes unfit for respiration. For which reason in the diving bell, after some time of stay under water, they are forced to come up and take in fresh air, or by some such means recruit it. But the famous Cornelius Drebell contrived not only a vessel to be rowed under water, but also a liquor to be carried in that vessel, that would supply the want of fresh air. The vessel was made for King James I. it carried twelve rowers, besides the passengers. It was tried in the river of Thames; and one of the persons that was in that submarine navigation was then alive, and told it one, who related the matter to our famous founder, the honourable and most ingenious Mr Boyle. As to the liquor, Mr Boyle saith, he discovered by a doctor of physick, who married Drebell's daughter, that it was used from time to time, when the air, in the submarine boat, was clogged by the breath of the company, and thereby made unfit for respiration; at which time, by untopping a vessel full of this liquor, he could speedily restore to the troubled air such a proportion of vital parts, as would make it again for a good while fit for respiration. The secret of this liquor Drebell would never disclose to above one person, who himself assured Mr Boyle what it was. Vide Boyle's Exp. Phys. Mech. of the Spring of the air, Exp. 41. in the digression. This story I have related from Mr Boyle, but at the same time much question, whether the virtues of the liquor were so effectual as reported.

And as too gross, so too rare an air is unfit for respiration. Not to mention the forced refractions made by the air pump, in

air (*d*), but those of the waters too (*e*). Without it

the following note; it is found, that even the extraordinary natural rarefractions, upon the tops of very high hills, much affect respiration. An ecclesiastical person, who had visited the high mountains of Armenia, on which some fancy the ark rested, told Mr Boyle, that whilst he was on the upper part of them, he was forced to fetch his breath oftener than he was wont: and taking notice of it when he came down, the people told him, that it was what happened to them when they were so high above the plane, and that it was a common observation among them. The like observation the same ecclesiastic made upon the top of a mountain in the Cevennes. So a learned traveller, and curious person, on one of the highest ridges of the Pyrenees, called Pic de Midi, found the air not so fit for respiration, as the common air, but he and his company were fain to breathe shorter and oftener than in the lower air. Vide Phil. Transact. No. 63. or Lowthorp's Abridg. Vol. 2. p. 226.

Such another relation the learned Joseph Acosta gives of himself, and his company, that, when they passed the high mountains of Peru, which they call Periacaca, (to which he saith, 'the Alps themselves seemed to them but as ordinary houses, in regard of high towers), he, and his companions, were surprized with such extreme pangs of straining and vomiting, not without casting up of blood too, and with so violent a distemper, that he concludes he should undoubtedly have died; but that this lasted not above three or four hours, before they came into a more convenient and natural temperature of the air.' All which he concludes, proceeded from the too great subtilty and delicacy of the air, which is not proportionable to human respiration, which requires a more gross and temperate air. Vide Boyle, ubi supra.

Thus it appears, that an air too subtle, rare and light, is unfit for respiration: but the cause is not the subtilty, or too great delicacy, as Mr Boyle thinks, but the too great lightness thereof, which renders it unable to be a counterbalance, or an antagonist to the heart, and all the muscles ministering to respiration, and the diastol of the heart. Of which see book 4. chap. 7. note 1.

And as our inability to live in too rare and light an air, may discourage those vain attempts of flying, and whimsies of passing to the moon, etc. so our being able to bear an heavier state of the air is an excellent provision for mens occasions in mines, and other great depths of the earth; and those other greater pressures made upon the air, in the diving-bell, when we descend into great depths of the waters.

(*d*) That the inhabitants of the air, birds and insects, need the air as well as man, and other animals, is manifest from their speedy dying in too feculent, or too much rarified air; of which

most animals live scarce half a minute (*f*); and o-

see the preceding, and following note *f*. But yet birds and insects, some birds at least, can live in a rarer air than man. Thus Eagles, kites, herons, and divers other birds, that delight in high flights, are not affected with the rarity of the medium, as those persons were in the preceding note. So insects bear the air-pump long, as in the following note *f*.

(*e*) Creatures inhabiting the waters need the air, as well as other animals, yea, and fresh air too. The hydrocanthari of all sorts, the nymphae of gnats, and many other water-insects, have a singular faculty, and an admirable apparatus, to raise their back-parts to the top of the waters, and take in fresh air. It is pretty to see, for instance, the hydrocanthari come and thrust their tails out of the water, and take in a bubble of air, at the tip of their vaginae and tails, and then nimbly carry it down with them into the waters; and, when that is spent, or souled, to ascend again and recruit it.

So fishes also are well known to use respiration, by passing the water through their mouths and gills. But carps will live out of the water, only in the air; as is manifest by the experiment of their way of fattening them in Holland, and which hath been practised here in England; viz. they hang them up in a cellar, or some cool place, in wet moss in a small net, with their heads out, and feed them with white bread soaked in milk, for many days. This was told me by a person very curious, and of great honour and eminence, whose word, if I had leave to name him, no body would question: and it being an instance of the respiration of fishes very singular and somewhat out of the way, I have for the reader's diversion taken notice of it.

(*f*) By experiments I made myself in the air-pump, in September and October, 1704, I observed that animals whose hearts have two ventricles, and no foramen ovale, as birds, dogs, cats, rats, mice, etc. die in less than half a minute, counting from the very first exsuction; especially in a small receiver.

A mole (which I suspected might have borne more than other quadrupeds) died in one minute, without recovery, in a large receiver; and doubtless would hardly have survived half a minute in a small receiver. A bat, although wounded, sustained the pump two minutes, and revived upon the re-admission of the air. After that, he remained four minutes and a half, and revived. Lastly, after he had been five minutes, he continued gasping for a time, and after twenty minutes I re-admitted the air, but the bat never revived.

As for insects; wasps, bees, hornets, grasshoppers, and lady-cows, seemed dead in appearance in two minutes, but revived in the open air in two or three hours time, notwithstanding they had been in vacuo twenty-four hours.

The ear-wig, the great staphylinus, the great black lowfy bee-

thers that are the most accustomed to the want of it, live not without it many days.

And not only animals themselves, but even trees and plants, and the whole vegetable race, owe their vegetation and life to this useful element; as will appear when I come to speak of them, and is manifest from their glory and verdure in a free air, and their becoming pale and sickly, and languishing and dying, when by any means excluded from it (g).

Thus useful, thus necessary, is the air to the life

tle, and some other insects, would seem unconcerned at the vacuum a good while, and lie as dead; but revive in the air, although some had lain sixteen hours in the exhausted receiver.

Snails bear the air-pump prodigiously, especially those in shells; two of which lay above twenty-four hours, and seemed not much affected. The same snails I left in twenty-eight hours more after a second exhaustion, and found one of them quite dead, but the other revived.

Frogs and toads bear the pump long, especially the former. A large toad, found in the house, died irrecoverably in less than six hours. Another toad and frog I put in together, and the toad was seemingly dead in two hours, but the frog just alive. After they had remained there eleven hours, and seemingly dead, the frog recovered in the open air, only weak, but the toad was quite dead. The same frog being put in again for twenty-seven hours then quite died.

The animalcules in pepper water, remained in vacuo twenty-four hours. And after they had been exposed a day or two to the open air, I found some of them dead, some alive.

(g) That the air is the principal cause of the vegetation of plants, Borelli proves, in his excellent book, *De Mot. Animal.* vol. 2. prop. 181. And in the next proposition, he assureth, 'In plantis quoque peragi aeris respirationem quandam imperfectam, a qua earum vita pendet, et conservatur.' But of this more, when I come to survey vegetables.

'Some lettuce-seed being sown upon some earth in the open air, and some of the same seed, at the same time, upon other earth in a glass-receiver of the pneumatic engine, afterwards exhausted of air: the seed exposed to the air, was grown up an inch and half high within eight days; but that in the exhausted receiver not at all. And air being again admitted into the same emptied receiver, to see whether any of the seed would then come up, it was found, that in the space of one week, it was grown up to the height of two or three inches.' Vide *Phil. Trans.* No. 23. Lowth. Abridg. vol. 2. p. 206.

of the animated creatures; and no less is it to the motion and conveyance of many of them. All the winged tribes owe their flight and buoyancy (*b*) to it, as shall be shewn in a proper place: And even the watry inhabitants themselves cannot ascend and descend into their element well without it (*i*).

(*b*) 'In volucribus pulmones perforati aerem inspiratum in totam ventris cavitatem admittunt. Hujus ratio, ut propter corporis truncum aere repletum et quasi extensum, ipsa magis volatilia evadant, faciliusque ab aere externo, propter intimi periculis, sustententur. Equidem pisces, quo levius in aquis natent, in abdomine vesicas aere inflatas gestant: pariter et volucres, propter corporis truncum aere impletum et quasi inflatum, nudo aeri incumbentes, minus gravantur, proindeque levius et expeditius volant.' Wills de Anim. Brut. p. 1. c. 3.

(*i*) 'Fishes, by reason of the bladder of air within them, can sustain or keep themselves in any depth of water: for the air in that bladder being more or less compressed, according to the depth the fish swims at, takes up more or less space; and consequently, the body of the fish, part of whose bulk this bladder is, is greater or less according to the several depths, and yet retains the same weight. Now, the rule *de insidentibus humida* is, that a body, that is heavier than so much water, as is equal in quantity to the bulk of it, will sink; a body that is lighter will swim; a body of equal weight will rest in any part of the water. By this rule, if the fish, in the middle region of the water, be of equal weight to the water, that is, commensurate to the bulk of it, the fish will rest there, without any tendency upwards or downwards: and if the fish be deeper in the water, the bulk of the fish becoming less by the compression of the bladder, and yet retaining the same weight, it will sink and rest at the bottom. And on the other side, if the fish be higher than the middle region, the air dilating itself, and the bulk of the fish consequently increasing, but not the weight, the fish will rise upwards, and rest at the top of the water. Perhaps, the fish by some action can emit air out of its bladder;—and, when not enough, take in air,—and then it will not be wondered, that there should be always a fit proportion of air in all fishes to serve their use,' etc. Then follows a method of Mr Boyle's to experiment the truth of this. After which, in Mr Lowthorp's abridgement, follow Mr Ray's observations. 'I think that— hath hit upon the true use of the swimming bladders in fishes. For, 1. It hath been observed, that if the swimming-bladder of any fish be pricked or broken, such a fish sinks presently to the bottom, and can neither support or raise itself up in the water. 2. Flat fishes, as soles, plaice, etc. which lie always grovelling at the

But it would be tedious to descend too far into particulars, to reckon up the many benefits of this noble appendage of our globe in many useful engines (*k*), in many of the functions and operations of nature (*l*), in the conveyance of sounds; and a

‘bottom, have no swimming-bladders that ever I could find.
 ‘3. In most fishes there is a manifest channel leading from the gullet—to the said bladder, which, without doubt, serves for the conveying air thereunto.—In the coat of this bladder is a musculous power to contract it when the fish lists.’ See more very curious observations, relating to this matter, of the late great Mr Ray, as also of the curious anonymous gentleman, in the ingenious Mr Lowthorp’s abridgement before cited, p. 845. from *Philosoph. Transf.* No. 114 115.

(*k*) Among the engines in which the air is useful, pumps may be accounted not contemptible ones, and divers other hydraulical engines, which need not to be particularly insisted on. In these the water was imagined to rise by the power of suction, to avoid a vacuum, and such unintelligible stuff; but the justly famous Mr Boyle was the first that solved these phaenomena by the weight of the atmosphere. His ingenious and curious observations and experiments relating hereto, may be seen in his little tract, *Of the Cause of Attraction by Suction*, and divers others of his tracts.

(*l*) It would be endless to specify the uses of air in nature’s operations: I shall therefore, for a sample only, name its great use to the world in conserving animated bodies, whether endowed with animal or vegetative life, and its contrary quality of dissolving other bodies; by which means many bodies that would prove nuisances to the world, are put out of the way, by being reduced into their first principles, as we say, and so embodied with the earth again. Of its faculty as a menstruum, or its power to dissolve bodies, I may instance in crystal glasses: which, with long keeping, especially if not used, will in time be reduced to a powder, as I have seen. So divers minerals, earths, stones, fossil-shells, wood, etc. which, from Noah’s flood, at least for many ages, have lain under ground, so secure from corruption, that, on the contrary, they have been thereby made much the stronger, have in the open air soon mouldered away. Of which last, Mr Boyle gives an instance (from the *Dissertation de admirandis Hungar. Aquis*) of a great oak, like a huge beam, dug out of a salt-mine in Transilvania, ‘so hard, that it would not easily be wrought upon by iron tools; yet, being exposed to the air out of the mine, it became so rotten, that in four days it was easy to be broken, and crumbled between one’s fingers.’ Boyle’s *Suspicion* about some hidden qualities in the air, p. 28. So the trees turned out of the earth by the breaches

thousand things besides. And I shall but just mention the admirable use of our atmosphere in ministering to the enlightning of the world, by its reflecting the light of the heavenly bodies to us (*m*); and refracting the sun-beams to our eye, before it ever surmounteth our horizon (*n*); by which means the day

at West-Thurrock and Dagenham, near me, although probably no other than alder, and interred many ages ago in a rotten oazy mould, were so exceedingly tough, hard, and sound at first, that I could make but little impressions on them with the strokes of an ax: but being exposed to the air and water, soon became so rotten as to be crumbled between the fingers. See my observations in Philos. Transact. No. 335.

(*m*) 'By reflecting the light of the heavenly bodies to us,' I mean that whiteness or lightness which is in the air in the day-time, caused by the rays of light striking upon the particles of the atmosphere, as well as upon the clouds above, and the other objects beneath upon the earth. To the same cause also we owe the twilight, viz. to the sun-beams touching the uppermost particles of our atmosphere, which they do when the sun is about eighteen degrees beneath the horizon. And as the beams reach more and more of the airy particles, so darkness goes off, and day-light comes on and increaseth. For an exemplification of this, the experiment may serve of transmitting a few rays of the sun through a small hole into a dark room: by which means the rays which meet with dust, and other particles flying in the air, are rendered visible; or which amounts to the same, those swimming small bodies are rendered visible, by their reflecting the light of the sun-beams to the eye, which without such reflection, would itself be invisible.

The azure colour of the sky Sir Isaac Newton attributes to vapours beginning to condense, and that are not able to reflect the other colours. V. Optic. l. 2. par. 3. prop. 7.

(*n*) By the refractive power of the air, the sun, and the other heavenly bodies seem higher than really they are, especially near the horizon. What the refractions amount unto, what variations they have, and what alterations in time they cause, may be briefly seen in a little book called, *The Artificial Clock maker*, chap. 11.

Although this infictive quality of the air be a great inconvenience and confusion of astronomical observations;—yet it is not without some considerable benefit to navigation; and indeed in some cases, the benefit thereby obtained is much greater than would be the benefit of having the ray proceed in an exact straight line, [Then he mentions the benefit hereof to the polar parts of the world]. 'But this by the by (saith he).

is protracted throughout the whole globe; and the long and dismal nights are shortened in the frigid zones, and day sooner approacheth them; yea, the sun itself riseth in appearance, (when really it is absent from them), to the great comfort of those forlorn places (e).

But passing by all these things with only a bare mention, and wholly omitting others that might have been named, I shall only insist upon the excellent use of this noble circumambient companion of our globe, in respect of two of its meteors, the winds, and the clouds and rain (p).

'The great advantage I consider therein, is the first discovery of land upon the sea; for by means hereof, the tops of hills and lands are raised up into the air, so as to be discoverable several leagues farther off on the sea than they would be, were there no such refraction, which is of great benefit to navigation for steering their course in the night, when they approach near land; and likewise for directing them in the day-time, much more certainly than the most exact celestial observations could do by the help of an uninflected ray, especially in such places as they have no soundings.' [Then he proposes a method to find, by these means, the distance of objects at sea]. V. Dr Hook's Post. Works, Lect. of Nav. p. 466.

(e) 'Cum Belgae in nova Zembla hybernarent, sol. illis apparuit 16 diebus citius quam revera in horizonte existeret, hoc est, cum adhuc infra horizontem depressus esset quatuor circiter gradibus, et quidem aere sereno.' Var. Geog. c. 19. pro. 22. [These Hollanders] 'found, that the night in that place shortened no less than a whole month; which must needs be a very great comfort to all such places as live very far towards the north and south poles, where length of night, and want of seeing the sun, cannot chuse but be very tedious and irksome.' Hook, *ibid*.

[By means of the refractions] 'we found the sun to rise twenty minutes before it should; and in the evening to remain above the horizon twenty minutes, or thereabouts, longer than it should.' Cap. James's Jour. in Boyle of cold. tit. 28. p. 190.

(p) 'Aer in nubes cogitur; humoremque colligens terram auget imbribus: tum effluens hue et illuc, ventos efficit. Idem annuus frigor et calorem facit varietates: idemque et volatus alitum sustinet, et spiritu ductus alit et sustentat animantes.' Cic. de Nat. Dear. l. 2. c. 39.

CHAP. II.

Of the WINDS (a).

TO pass by other considerations, whereby I might demonstrate the winds to be the infinite Creator's contrivance, I shall insist only upon their great usefulness to the world. And so great is

(a) 'Venus est aer fluens,' is Seneca's definition. Na. Qu. l. 5. And as wind is a current of the air, so that which excites or alters its currents, may be justly said to be the cause of the winds. An equipoise of the atmosphere produceth a calm: but if that equipoise be more or less taken off, a stream of air, or wind, is thereby accordingly produced either stronger or weaker, swifter or slower. And divers things there are that may make such alterations in the equipoise or balance of the atmosphere, viz. eruptions of vapours from sea or land; rarefactions and condensations in one place more than another; the falling of rain, pressure of the clouds, etc. Pliny, l. 2. c. 45, tells us of a certain cavern in Dalmatia, called Senta, 'in quem (saith he) dejecto levi pondere, quamvis tranquillo die, turbini similis emicat procella.' But as to caves it is observed, that they often emit winds more or less. Dr Connor, taking notice of this matter, specifies these, 'In regno Neapolitano ex immani Cumanae Sibyllaeantro tenuem ventum effluentem percepi.' The like he observed at the caves at Baia, and in some of the mines of Germany, and in the large salt-mines of Cracow in Poland. 'Ubi (saith he) opifices, et ipse fodinae dominus Andreas Morstin, Nob. Polonus, mihi asseruerunt, quod tanta aliquando ventorum tempestas exambagiosis hujus fodinae recessibus surgere solebat, quod laborantes fossiores humi prosternebat, nec non portas et domicilia (quae sibi in hac fodina artifices extruunt) penitus evertibat.' Bern. Con. Dis. Med. phys. p. 33. art. 3.

And as great caves, so great lakes sometimes send forth winds. Gassendus saith the Lacus Legnius doth, 'E quo dum exoritur fumus, nubes haud dubie creanda est, quae sit brevi in tempestatem saevissimam exoneranda,' Gas. Vir. Peir. l. 5. p. 417. But the most universal and constant alterations of the balance of the atmosphere, are from heat and cold. This is manifest in the general trade-winds, blowing all the year between the tropics from east to west: if the cause thereof be, as some ingenious men imagine, the sun's daily progress round that part of the globe, and by his heat rarefying one part of the air, whilst the

their use, and of such absolute necessity are they to the salubrity of the atmosphere, that all the world would be poisoned without those agitations thereof. We find how putrid, fetid, and unfit for respiration, as well as health and pleasure, a stagnating, confined, pent-up air is. And if the whole mass of air and vapours was always at rest, and without motion, instead of refreshing and animating, it would suffocate,

cooler and heavier air behind presseth after. So the sea and land breezes in note (c) p. 49. And so in our climate, the northerly and southerly winds (commonly esteemed the causes of cold and warm weather) are really the effects of the cold or warmth of the atmosphere: of which I have had so many confirmations, that I have no doubt of it. As for instance, it is not uncommon to see a warm southerly wind, suddenly changed to the north, by the fall of snow or hail; to see the wind in a frosty, cold morning, north, and when the sun hath well warmed the earth and air, you may observe it to wheel about towards the southerly quarters; and again to turn northerly or easterly in the cold evening. It is from hence also, that in thunder showers the wind and clouds are oftentimes contrary to one another, especially if hail falls, the sultry weather below directing the wind one way, and the cold above the clouds another way. I took notice, upon March the 10. 1710-11. (and divers such like instances I have had before and since) that the morning was warm, and what wind stirred was west-south-west, but the clouds were thick and black (as generally they are when snow ensues). A little before noon the wind veered about to north by west, and sometimes to other points, the clouds at the same time flying some north by west, some south west: about one of the clock it rained apace, the clouds flying sometimes north-east, then north, and at last both wind and clouds settled north by west; at which time sleet fell plentifully, and it grew very cold. From all which I observe, 1. That although our region below was warm, the region of the clouds was cold, as the black, snowy clouds shewed. 2. That the struggle between the warmth of ours, and the cold of the cloudy region, stopped the airy currents of both regions. 3. That the falling of the snow through our warmer air melted into rain at first; but that it became sleet after the superior cold had conquered the inferior warmth. 4. That, as that cold prevailed by degrees, so by degrees it wheeled about both the winds and clouds from the northwards towards the south.

Hippocrates, l. 2. De Vict. Orat. 'Omnes ventos vel a nive, glacie, vehementi gelu, fluminibus, etc. spirare necesse judicat' Bartholin. de usu Nivis, c. 1.

and poison all the world : but the perpetual commotions it receives from the gales and storms, keep it pure and healthful (b).

Neither are those ventilations beneficial only to the health, but to the pleasure also of the inhabitants of the terraqueous globe : witness the gales which *fair in* us in the heat of summer ; without which, even this our temperate zone, men are scarce able to perform the labours of their calling, or not without danger of health and life (c). But especially, witness the perpetual gales which throughout the whole year

(b) ' It is well observed in my lord Howard's voyage to Constantinople, that at Vienna they have frequent winds, which if they cease long in summer, the plague often ensues : so that it is now grown into a proverb, that if Austria be not windy, it is subject to contagion.' Bohun of Wind, p. 223.

From some such commotions of the air I imagine it is, that at Grand Cairo the plague immediately ceases, as soon as the Nile begins to overflow ; although Mr Boyle attributes it to nitrous corpuscles. Determ. Nat. of Effluv. chap. 4.

' Nulla enim propemodum regio est, quae non habet aliquem flatum ex se nascentem, et circa se cadentem.'

' Inter caetera itaque providentiae opera, hoc quoque aliquis, ut dignum admiratione, suspexerit. Non enim ex una causa, ventos aut invenit, aut per diversa disposuit : sed primum ut aera non sinerent pigrescere, sed assidua vexatione utilem redderent, vitalemque tracturis.' Sen. Nat. Quaest. l. 5. c. 17. 18.

All this is more evident, from the cause assigned to malignant epidemical diseases, particularly the plague, by my ingenious learned friend, Dr Mead ; and that is, an hot and moist temperament of the air, which is observed by Hippocrates, Galen, and the general histories of epidemical diseases, to attend those distempers. Vide Mead of Poisons, Essay 5. p. 161. But indeed, whether the cause be this, or poisonous, malignant exhalations or animalcules, as others think, the winds are however very salutiferous in such cases, in cooling the air, and dispersing and driving away the moist or pestiferous vapours.

(c) July 8. 1707, (called, for some time after, the hot Tuesday) was so excessively hot and suffocating, by reason there was no wind stirring, that divers persons died, or were in great danger of death, in their harvest-work. Particularly one who had formerly been my servant, a healthy, lusty, young man, was killed by the heat ; and several horses on the road dropped down and died the same day.

In the foregoing notes, having taken notice of some things re-

do fan the torrid zone, and make that climate an healthful and pleasant habitation, which would otherwise be scarce habitable.

To these I might add many other great conveniences of the winds in various engines, and various *uses*. *usages.* I might particularly insist upon its great *use* use to transport men to the farthest distant regions of

lating to heat, although it be somewhat out of the way. I hope the reader will excuse me, if I entertain him with some observations I have made about the heat of the air under the line, compared with the heat of our bodies. J. Patrick, who, as he is very accurate in making barometrical and thermometrical instruments, had the curiosity, for the nicer adjusting his thermometers, to send two abroad (under the care of two very sensible ingenious men), one to the northern lat. of 81; the other to the parts under the equinoctial: in these two different climates, the places were marked where the spirits stood at the severest cold and greatest heat. And according to these observations he graduated his thermometers. With his standard I compared my standard thermometer, from all the degrees of cold, I could make with Sal Armoniac, etc. to the greatest degrees of heat our thermometers would reach to. And with the same thermometer of mine, I experimented the greatest heat of my body, in July, 1709. First in an hot day without exercise, by putting the ball of my thermometer under my arm-pits, and other hottest parts of my body. By which means the spirits were raised 284 tenths of an inch above the ball. After that, in a much hotter day, and indeed nearly as hot as any day with us, and after I had heated myself with strong exercise too, as much as I could well bear, I again tried the same experiment, but could not get the spirits above 288 tenths; which I thought an inconsiderable difference for so seemingly a very different heat of my body. But from some experiments I have made, (although I have unfortunately forgotten them), in very cold weather, I imagine the heat of an healthy body to be always much the same in the warmest parts thereof, both in summer and winter. Now between those very degrees of 284, and 288, the point of the equatorial heat falleth. From which observation it appears, that there is pretty nearly an equal contemperament of the warmth of our bodies, to that of the hottest part of the atmosphere inhabited by us.

If the proportion of the degrees of heat be desired from the freezing-point, to the winter, spring, and summer air, the heat of man's body, of heated water, melted metals, and so to actual fire; an account may be met with of it, by my most ingenious friend, the great Sir Isaac Newton, in Phil. Transact. No 270.

the world (*d*); and I might particularly speak of the general and coasting trade-winds, the sea and land-breezes (*e*); the one serving to carry the mariner in long voyages from east to west; the other serving to waft him to particular places; the one serving to carry him into his harbour, the other to bring him out. But I should go too far to take notice of all particulars (*f*). Leaving therefore the winds, I proceed, in the next place, to clouds and rain.

(*d*) 'In hoc providentia ac dispositor ille mundi Deus, aera ventis exercendum dedit,—non ut nos classes partem freti occupaturas compleremus milite armato, etc. Dedit illi ventos ad custodiendam coeli terrarumque temperiem, ad evocandas superprimendasque aquas, ad alendos satorum atque arborum fructus; quos ad maturitatem cum aliis causis adducit ipsa jactatio, attrahens cibum in summa, et ne torpeat, promovens. Dedit ventos ad ulteriora noscenda: fuisset enim imperitum animal, et sine magna experientia rerum! mo, si circumscriberetur natalis soli sine. Dedit ventos ut commoda cujusque regionis fierent communia; non ut legiones equitemque gestarent, nec ut perniciosa gentibus arma transveherent.' Seneca, *ibid*.

(*e*) 'Sea-breezes commonly rise in the morning about nine o' clock.—They first approach the shore gently, as if they were afraid to come near it.—It comes in a fine, small, black curl upon the water, whereas all the sea between it and the shore, not yet reached by it, is as smooth and even as glass in comparison. In half an hour's time after it has reached the shore, it fans pretty briskly, and so increaseth gradually till twelve o' clock; then it is commonly the strongest, and lasts so till two or three, a very brisk gale.—After three it begins to die away again, and gradually withdraws its force till all is spent; and about five o' clock—it is lulled asleep, and comes no more till next morning.

'And as the sea-breezes do blow in the day, and rest in the night; so on the contrary [the land breezes] blow in the night, and rest in the day, alternately succeeding each other.—They spring up between six and twelve at night, and last till six, eight, or ten, in the morning.' Dampier's Discourse of Winds, chap. 4.

(*f*) One thing more I believe some of my friends will expect from me is, that I shew the result of comparing my own observations of the winds, with others they know I have from Ireland, Switzerland, Italy, France, New-England, and some of our parts in England. But the observations being, some of them, but of one year, and most of the rest of but a few years, I have not been able to determine any great matters. The chief of what

C H A P. III.

Of the CLOUDS and RAIN.

TH E clouds and rain (a) we shall find to be no less useful meteors than the last mentioned; as is manifest in the refreshing pleasant shades which

I have observed is, that the winds in all these places seldom agree; but when they most certainly do so, it is commonly when the winds are strong, and of long continuance in the same quarter: and more, I think, in the northerly and easterly, than other points. Also, a strong wind in one place, is oftentimes a weak one in another place, or moderate, according as places have been nearer or farther distant. V. Phil. Trans. No. 297, and 321. But to give a good and tolerable account of this, or any other of the weather, it is necessary to have good histories thereof from all parts; which as yet we have but few of, and they imperfect, for want of longer and sufficient observations.

(a) Clouds and rain are made of vapours raised from water, or moisture only. So that I utterly exclude the notion of dry, terrene exhalations, or fumes, talked much of by most philosophers; fumes being really no other than the humid parts of bodies respectively dry.

These vapours are demonstratively no other than small bubbles, or vesiculae, detached from the waters by the power of the solar, or subterraneous heat, or both. Of which, see book 2. chap. 5. note (c). And being lighter than the atmosphere, are buoyed up thereby, until they become of an equal weight therewith, in some of its regions aloft in the air, or nearer the earth; in which those vapours are formed into clouds, rain, snow, hail, lightning, dew, mists, and other meteors.

In this formation of meteors the grand agent is cold, which commonly, if not always, occupies the superior regions of the air; as is manifest from those mountains which exalt their lofty tops into the upper and middle regions, and are always covered with snow and ice.

This cold, if it approaches near the earth, presently precipitates the vapours, either in dews; or if the vapours more copiously ascend, and soon meet the cold, they are then condensed into misting, or else into showers of small rain, falling in numerous, thick, small drops; but if those vapours are not only copious, but also as heavy as our lower air itself, (by means their bladders are thick and fuller of water), in this case they become visible,

the clouds afford, and the fertile dews and showers which they pour down on the trees and plants, which

swim but a little height above the earth, and make what we call a mist or fog. But if they are a degree lighter, so as to mount higher, but not any great height, as also meet not with cold enough to condense them, nor wind to dissipate them, they then form an heavy, thick, dark sky, lasting oftentimes for several weeks without either sun or rain. And in this case, I have scarce ever known it to rain, till it hath been first fair, and then foul. And Mr Clarke, an ingenious clergyman of Norfolk, who in his lifetime, long before me, took notice of it, and kept a register of the weather for thirty years, which his learned grandson, Dr Samuel Clarke, put into my hands, he (I say) saith, he scarce ever observed the rule to fail in all that time; only he adds, 'If the wind be in some of the easterly points.' But I have observed the same to happen, be the wind where it will. And from what hath been said, the case is easily accounted for, viz whilst the vapours remain in the same state, the weather doth so too. And such weather is generally attended with moderate warmth, and with little or no wind to disturb the vapours, and an heavy atmosphere to support them, the barometer being commonly high then. But when the cold approacheth, and by condensing drives the vapours into clouds or drops, then is way made for the sun-beams, till the same vapours, being by further condensation formed into rain, fall down in drops.

The cold's approaching the vapours, and consequently the alteration of such dark weather, I have before-hand perceived, by some few small drops of rain, hail, or snow, now and then falling, before any alteration hath been in the weather; which I take to be from the cold meeting some of the straggling vapours, or the uppermost of them, and condensing them into drops, before it arrives unto, and exerts itself upon the main body of vapours below.

I have more largely than ordinary insisted upon this part of the weather, partly as being somewhat out of the way; but chiefly, because it gives light to many other phaenomena of the weather. Particularly we may hence discover the original of clouds, rain, hail, and snow; that they are vapours carried aloft by the gravity of the air, which meeting together so as to make a fog above, they thereby form a cloud. If the cold condenseth them into drops, they then fall in rain, if the cold be not intense enough to freeze them: but if the cold freezeth them in the clouds, or in their fall through the air, they then become hail or snow.

As to lightning, and other enkindled vapours, I need say little in this place, and shall therefore only observe, that they owe also their rise to vapours; but such vapours as are detached from mineral juices, or at least that are mingled with them, and are fired by fermentation.

Another phaenomenon resolvable from what hath been said, is,

would languish and die with perpetual drought, but are hereby made verdant and flourishing, gay and

why a cold is always a wet summer, viz. because the vapours rising plentifully then, are by the cold soon collected into rain. A remarkable instance of this we had in the summer of 1708, part of which, especially about the solstice, was much colder than usually. On June 12. it was so cold, that my thermometer was near the point of hoar-frost; and in some places I heard there was an hoar-frost; and during all the cool weather of that month, we had frequent and large rains, so that the whole month's rain amounted to above two inches depth, which is a large quantity for Upminster, even in the wettest months. And not only with us at Upminster, but in other places, particularly at Zurich in Switzerland, they seem to have had as unseasonable cold and wet as we. *'Fuit hic mensis—praeter modum humidus, et magno quidem vegetabilibus hominibusque damno. Multum computruit foenum,'* etc. complains the industrious and learned D. J. J. Scheuehzer: of which, and other particulars, I have given a large account in Phil. Transf. No. 321.

In which transaction I have observed further, that about the equinoxes we, at Upminster at least, have oftentimes more rain than at other seasons. The reason of which is manifest from what hath been said, viz. in spring, when the earth and waters are loosed from the brumal constipations, the vapours arise in great plenty: and the like they do in autumn, when the summer heats, that both dissipated them, and warmed the superior regions, are abated; and then the cold of the superior regions meeting them, condenseth them into showers, more plentifully than at other seasons, when either the vapours are fewer, or the cold that is to condense them is less.

The manner how vapours are precipitated by the cold, or reduced into drops, I conceive to be thus: vapours being, as I said, no other than inflated vesiculae of water; when they meet with a colder air than what is contained in them, the contained air is reduced into a less space, and the watery shell or case rendered thicker by that means, so as to become heavier than the air, by which they are buoyed up, and consequently must needs fall down. Also many of those thickened vesiculae run into one, and so form drops, greater or smaller, according to the quantity of vapours collected together.

As to the rain of different places, I have in some of our transactions assigned the quantities; particularly in the last cited transaction, I have assigned these, viz. the depth of the rain one year with another, in English measure, if it was to stagnate on the earth, would amount unto, at Townly in Lancashire, 42 inches and a half; at Upminster in Essex, 19 inches and a quarter; at Zurich in Switzerland, 32 inches and a quarter; at Pisa in Italy, 43 inches and a quarter; at Paris in France, 19 inches; and at Lille in Flanders, 24 inches.

ornamental; so that (as the psalmist saith, Psal. lxxv. 12. 13.) *The little hills rejoice on every side, and the valleys shout for joy, they also sing.*

It would be endless to reckon up the bloody and other prodigious rains taken notice of by historians, and other authors, as praeternatural and ominous accidents; but if strictly pried into, will be found owing to natural causes: of which, for the reader's satisfaction, I will give an instance or two. A bloody rain was imagined to have fallen in France, which put the country people into so great a fright, that they left their work in the fields, and in great haste flew to the neighbouring houses. Peiresk, then in the neighbourhood, strictly inquiring into the cause, found it to be only red drops coming from a sort of butterfly that flew about in great numbers at that time, as he concluded from seeing such red drops come from them; and because these drops were laid, 'Non supra aedificia, non in devexis lapidum superficibus, uti debuerat contingere, si e coelo sanguine pluisset; sed in subcavis potius et in foraminibus.—Accessit, quod parietes iis tingebantur, non quia in mediis oppidis, sed qui agrorum vicini erant, neque secundum partes elatiores, sed ad mediocrem solum altitudinem, quantum volitare papilioes solent.' Gassend. in vit. Peiresk, l. 2. p. 156.

So Dr Merret saith also, 'Pluvia sanguinis quam certissime constat esse tantum insectorum excrementa; pluvia tritici nihil aliud esse quam hederæ bacciferae grana a sturnis devorata excretaque comparanti liquidissime patet.' Pinax rerum, etc. p. 220.

The curious Wormius tells of the raining of brimstone, An. 1646, Maij 16. 'Hic Hafniae cum ingenti pluvia tota urbs, omnesque ita inundarentur plateae, ut gressus hominum impediret, sulphureoque odore aerem inficeret, dilapsis aliquantulum aquis, quibusdam in locis colligere licuit sulphureum pulverem, cujus portionem fervo, colore, odore, et aliis verum sulphur ferentem.' Mus. Worm. l. 1. c. 11. sect. 1.

Together with the rain we might take notice of other meteors, particularly snow; which although an irksome guest, yet hath its great uses, if all be true that the famous T. Bortholin saith of it, who wrote a book de Nivis Usu Medico. In which he shews of what great use snow is in fructifying the earth, preserving from the plague, curing fevers, cholics, head-aches, tooth aches, sore-eyes, pluries, (for which use, he saith, his country-women of Denmark keep snow-water gathered in March), also in prolonging life, (of which he instanceth in the Alpin inhabitants, that live to a great age), and preserving dead bodies; instances of which he gives in persons buried under the snow in passing the Alps, which are found uncorrupted in the summer, when the snow is melted; which sad spectacle he himself was an eye-witness of. And at Spitzberg in Greenland, dead bodies remain entire and uncorrupted for thirty years. And lastly, concerning such

And if to these uses, we should add the origin of fountains and rivers to vapours and the rains, as some of the most eminent modern philosophers (b)

as are so preserved when slain, he saith they remain in the same posture and figure: of which he gives this odd example. 'Visum id extra urbem nostram [Hafniam] quum, 11 Feb. 1659. oppug-
' nantes hostes repellerentur, magnaue strage occumberent; alii
' enim rigidi iratum vultum ostendebant, alii oculos elatos; alii
' ore diducto ringentes, alii brachiis extensis gladium minari, alii
' alio situ prostrati jacebant.' Bar. de usu niv. c. 12.

But although snow be attended with the effects here named, and others specified by the learned Bartholin; yet this is not to be attributed to any peculiar virtue in the snow, but some other cause. Thus when it is said to fructify the earth, it doth so by guarding the corn or other vegetables against the intenser cold of the air, especially the cold piercing winds; which the husbandmen observe to be the most injurious to their corn of all weathers. So for conserving dead bodies, it doth it by constipating such bodies, and preventing all such fermentations or internal conflicts of their particles, as would produce corruption.

Such an example as the preceding is said to have happened some years ago at Paris, in digging in a cellar for supposed hidden treasure; in which, after digging some hours, the maid going to call her master, found them all in their digging postures, but dead. This being noised abroad, brought in not only the people, but magistrates also, who found them accordingly; 'Ille qui
' ligone terram effoderat, et socius qui palla effosam terram re-
' moverat, ambo pedibus stabant, quasi suo quisque operi affixus
' incubuisset; uxor unius quasi ab opere defessa in scamno, solici-
' to quodam vultu, sedebat, inclinato in palmam manus genibus
' innitentis capite; puerulus laxatis braccis in margine excavatae
' foveae defixis in terram oculis alvum exonerabat; omnes in na-
' turali situ, carnae tanquam statuae rigidi, apertis oculis et vul-
' tu vitam quasi respirante, exanimis stabant.' Dr Bern. Conner, Dissert. Med. Phys. p. 15.

The doctor attributes all this to cold; but I scarce think there could be cold enough to do all this at Paris, and in a cellar too. But his following stories are not improbable, of men and cattle killed with cold, that remained in the very same posture in which they died; of which he gives, from a Spanish captain, this instance, that happened two years before, of a soldier who unfortunately straggled from his company that were foraging, and was killed with the cold, but was thought to have fallen into the enemies hands. But soon after their return to their quarters, they saw their comrade returning, sitting on horseback; and coming to congratulate him, found him dead, and that he had been brought thither in the same posture on horseback, notwithstanding the jolting of the horse. Ib. p. 18.

(b) Of this opinion was my late most ingenious and learned

have done, we should have another instance of the great use and benefit of that meteor.

And now, if we reflect upon this necessary appendage of the terraqueous globe, the atmosphere; and consider the absolute necessity thereof to many uses of our globe, and its great convenience to the whole: and in a word, that it answereth all the ends and purposes that we can suppose there can be for such an appendage: who can but own this to be the contrivance, the work of the great Creator? who would ever say or imagine such a body, so different from the globe it serves, could be made by chance, or be adapted so exactly to all those forementioned grand ends, by any other efficient than by the power and wisdom of the infinite God! who would not rather, from so noble a work, readily acknowledge the Workman (c), and as easily conclude the atmosphere to be made by God, as an instrument wrought by its power, any pneumatic engine, to be contrived and made by man!

C H A P. IV.

Of LIGHT.

THUS much for the first thing ministering to the terraqueous globe, the atmosphere and its meteors; the next appendage is LIGHT (a). Con-

sider, Mr Ray, whose reasons see in his *Physico-Theog. Discourses*, Disc. 2. ch. 2. p. 89, etc. So also my no less learned and ingenious friends, Dr Halley, and the late Dr Hook; many of the French virtuofos also, and divers other very considerable men before them, too many to be specified here.

(c) 'An Polycletum quidem admirabimur propter partium statuae—convenientiam ac proportionem? Naturam autem non modo non laudabimus, sed omni etiam arte privabimus, quae partium proportionem non solum extrinsecus more statuariorum, sed in profundo etiam servavit? Nonne et Polycletus ipse naturae est imitator, in quibus saltem eam potuit imitari? potuit autem in solis externis partibus in quibus artem consideravit.' With much more to the like purpose. Galen de Us. Part. 1.

7. c. 1.

(a) It is not worth while to enumerate the opinions of the

cerning which, I have in my survey of the heavens (*b*) shewed what admirable contrivances the infinitely wise Creator hath for the affording this noble, glorious, and comfortable benefit to other globes, as well as ours; the provision he hath made by moons, as well as by the sun, for the communication of it.

And now let us briefly consider the great necessity and use thereof to all our animal world. And this we shall find to be little less than the very life and pleasure of all those creatures. For what benefit would life be of, what pleasure, what comfort would it be for us to live in perpetual darkness? How could we provide ourselves with food and necessaries? How could we go about the least business, correspond with one another, or be of any use in the world, or any creatures be the same to us, without light, and those admirable organs of the body, which the great Creator hath adapted to the perception of that great benefit?

But now by the help of this admirable, this first-made (*c*), because most necessary, creature of God; by this, I say, all the animal world is enabled to go here and there, as their occasions call; they can transact their business by day, and refresh and recruit themselves by night, with rest and sleep. They can,

Aristotelians, Cartesians, and others, about the nature of light: Aristotle making it a quality; Cartes a pulsion, or motion of the globules of the second element. Vide Cartes Prin. p. 3. sect. 55. etc. But, with the moderns, I take light to consist of material particles, propagated from the sun, and other luminous bodies, not instantaneously, but in time, according to the notes following in this chapter. But not to insist upon other arguments for the proof of it, our noble founder hath proved the materiality of light and heat, from actual experiments on silver, copper, tin, lead, spelter, iron, tutenage, and other bodies, exposed (both naked and closely shut up) to the fire: all which were constantly found to receive an increment of weight. I wish he could have met with a favourable season to have tried his experiments with the sun-beams, as he intended. Vide Boyle's Exp. to make fire and flame ponderable.

(*b*) Astro-Theol. book 7.

(*c*) 'And God said, Let there be light, and there was light.' Gen. i. 3.

with admiration and pleasure, behold the glorious works of God; they can view the glories of the heavens, and see the beauties of the flowery fields, the gay attire of the feathered tribe, the exquisite garniture of many quadrupeds, insects, and other creatures; they can take in the delightful landships of divers countries and places; they can with admiration see the great Creator's wonderful art and contrivance in the parts of animals and vegetables: and, in a word, behold the harmony of this lower world, and of the globes above, and survey God's exquisite workmanship in every creature.

To all which I might add the improvements which the sagacity of men hath made of this noble creature of God, by the refractions and reflections of glasses. But it would be endless to enumerate all its particular uses and benefits to our world.

But before I leave this point, there are two things concerning light, which will deserve an especial remark; and that is, its swift and almost instantaneous motion, and its vast expansion.

1. It is a very great act of the providence of God, that so great a benefit as light is, is not long in its passage from place to place. For, was the motion thereof no swifter than the motion of the swiftest bodies on earth, such as of a bullet out of a great gun; or even of a sound (*d*), which is the swiftest motion

(*d*) It may not be ungrateful to the curious, to take notice of the velocity of these two things.

According to the observations of Mersennus, a bullet shot out of a great gun, flies 92 fathom in a second of time, (Vide Mers. Balist.) which is equal to 589 English feet and a half; and according to the computation of Mr Huygens, it would be 25 years in passing from the earth to the sun. But according to my own observations made with one of her late majesty's makers, and a very accurate pendulum-chronometer, a bullet at its first discharge, flies 510 yards in five half seconds, which is a mile in a little above 17 half seconds. And allowing the sun's distance to be, as in the next note, a bullet would be 32 years and a half in flying, with its utmost velocity, to the sun.

As to the velocity of sounds, see book iv. chap. 3. note second, according to which rate there mentioned, a sound would be

we have next to light, in this case light would take up its progress from the sun to us, above thirty-two years, at the rate of the first; and above seventeen years, at the rate of the latter motion.

The inconveniencies of which would be, its energy and vigour would be greatly cooled and abated; its rays would be less penetrant; and darkness would with greater difficulty and much sluggishness, be dissipated, especially by the fainter lights of our sublunary, luminous bodies. But passing with such prodigious velocity, with nearly the instantaneous swiftness of almost two hundred thousand English miles in one second of time (*e*), or, which is the same thing, being but about seven or eight minutes of an hour in coming from the sun to us, therefore with all security and speed, we receive the kindly effects and influences of that noble and useful creature of God.

2. Another thing of great consideration about light is, its vast expansion, its almost incomprehensible, and inconceivable extension, which, as a late

near 17 years and a half in flying as far as the distance is from the earth to the sun. Confer here the experiments of the Academi del Ciment. p. 140, etc.

(*e*) Mr Romer's ingenious hypothesis about the velocity of light, hath been established by the Royal Academy, and in the Observatory, for eight years, as our Phil. Trans. No. 136. observe from the Jour. des Scavans; our most eminent astronomers also in England admit it: but Dr Hook thinks, with Monsieur Cartes, the motion of light instantaneous, Hook's Post. Works, p. 77. And this he endeavours to explain, p. 130, etc.

What Mr Romer's hypothesis is, may be seen in the Phil. Trans. before cited: and also in the before-mentioned Sir Isaac Newton's Optics: 'Light is propagated from luminous bodies in time, and spends about seven or eight minutes of an hour in passing from the sun to the earth. This was first observed by Romer, and then by others, by means of the eclipses of the satellites of Jupiter. For these eclipses, when the earth is between the Sun and Jupiter, happen about seven or eight minutes sooner than they ought to do by the tables; and when the Earth is beyond the Sun, they happen about seven or eight minutes later than they ought to do: the reason being, that the light of the satellites hath farther to go in the latter case than in the former, by the diameter of the earth's orbit.' New Op. l. 2. par. 3. pro. 11.

ingenious author saith (*f*), 'is as boundless and unlimited as the universe itself, or the expanse of all material beings: the vastness of which is so great, that it exceeds the comprehension of man's understanding. Inasmuch, that very many have asserted it absolutely infinite, and without any limits or bounds.'

And that this noble creature of God is of this extent (*g*), is manifest from our seeing some of the farthest distant objects, the heavenly bodies, some with our naked eye, some with the help of optical instruments, and others in all probability farther and farther, with better and better instruments: and had we instruments of power equivalent to the extent of light, the luminous bodies of the utmost parts of the universe, would, for the same reason, be visible too.

Now, so far as the distance between the sun and the earth according to the computations in my *Astro-The.* b. i. c. 3. n. 2.) is 86,051,398 English miles; therefore, at the rate of 7 minutes and a half, or 450 seconds, in passing from the sun, light will be found to fly above 191,225 miles in one second of time.

(*f*) Dr Hook's *Posthumous Works*, *Lect. of Light*, p. 76.

(*g*) For the proof of this vast extent of light, I shall take the computation of the same great man, p. 77. 'If, saith he, we consider first, the vast distance between us and the sun, which from the best and latest observations in astronomy, is judged to be about 10,800 diameters of the earth, each of which is about 7925 English miles; therefore the sun's distance is 79,250,000 miles; and if we consider, that, according to the observations which I published to prove the motion of the earth, [which were observations of the parallax of some of the fixed stars in the head of Draco, made in 1699] 'the whole diameter of the orb, viz. 20,000, made the subtense of but one minute to one of the fix'd stars, which cannot therefore be less distant than 3,438 diameters of this great orb, and consequently 68,760,000 diameters of the earth: and if this star be one of the nearest, and that the stars that are of one degree lesser in magnitude (I mean not of the second magnitude, because there may be many degrees between the first and the second) be as much farther; and another sort yet smaller be three times as far; and a fourth four times as far, and so onward, possibly to some 100 degrees of magnitude, such as may be discovered by longer and longer telescopes; that they may be 100 times as far; then certainly this material expansion, a part of which we are, must be so great, that it will infinitely exceed our shallow conception to

Now, as light is of greatest use to impower us to see objects at all, so the extension thereof is no less useful to enable us to see objects afar off. By which means we are afforded a ken of those many glorious works of the infinite Creator, visible in the heavens, and can improve them to some of the noblest sciences, and most excellent uses of our own globe.

C H A P. V.

Of GRAVITY.

THE last thing subservient to our globe, that I shall take notice of, is GRAVITY (*a*) ; or, that tendency which bodies have to the centre of the earth.

' imagine. Now, by what I last mentioned, it is evident, that
' light extends itself to the utmost imaginable parts, and, by the
' help of telescopes, we collect the rays, and make them sensible
' to the eye, which are emitted from some of the almost in-
' conceivable remote objects, etc.—Nor is it only the great
' body of the sun, or the vast bodies of the fix'd stars, that are
' thus able to disperse the light through the vast expanse of the
' universe ; but the smallest spark of a lucid body, must do the
' very same thing, even the smallest globule struck from a steel
' by a flint,' etc.

(*a*) That there is such a thing as gravity, is manifest from its effects here upon earth ; and that the heavenly bodies attract or gravitate to one another, when placed at due distances, is made highly probable by Sir Isaac Newton. This attractive, or gravitating power, I take to be congenial to matter, and imprinted on all the matter of the universe by the Creator's Fiat at the creation. What the cause of it is, the Newtonian philosophy doth not pretend to determine for want of phaenomena, upon which foundation it is that that philosophy is grounded, and not upon chimerical and uncertain hypotheses : but whatever the cause is, that ' cause penetrates even to the centres of the sun and planets, ' without any diminution of its virtue ; and it acteth not according to the superficies of bodies, as mechanical causes do, ' but in proportion to the quantity of their solid matter : and ' lastly, it acteth all round it at immense distances, decreasing in ' duplicate proportion to those distances,' as Sir Isaac Newton saith, Princip. p. ult. What useful deductions, and what a rational philosophy, have been drawn from hence, may be seen in the same book.

In my *Astro-theology*, book vi. chap. 2. I have shewn of what absolute necessity, and what a noble contrivance this of gravity is, for keeping the several globes of the universe from shattering to pieces, as they evidently must do in a little time, by their swift

This attraction, or gravity, as its force is in a certain proportion, so makes the descent of bodies to be at a certain rate. And was it not for the resistance of the medium, all bodies would descend to the earth at the same rate; the lightest down, as swiftly as the heaviest mineral: as is manifest in the air-pump, in which the lightest feather, dust, etc. and a piece of lead, drop down seemingly in the same time, from the top to the bottom of a tall exhausted receiver.

The rate of the descent of heavy bodies, according to Galilæo, Mr Huygens, and Dr Halley after them, is 16 feet one inch in one second of time; and in more seconds, as the squares of those times. But in some accurate experiments made in St Paul's dome, June 9, 1710. at the height of 220 feet, the descent was scarcely 14 feet in the first second. The experiments were made in the presence of some very considerable members of the Royal Society, by Mr Hawksbee, their operator, with glass, hollow balls, some empty, some filled with quick-silver, the barometer at 297, the thermometer 60 degrees above freezing. The weight of the balls, their diameters, and time of their descent is in this table.

Balls fill'd with quicksilver.			Empty balls.		
Weight	Diameter.	Time.	Weight	Diameter.	Time.
Grains.	Ten. Inch.	half Second.	Grains.	Inch. Tent.	half Secon.
908	8	8	510	5 1	17
993	8	8 less.	642	5 2	16
866	8	8	599	5 1	16
747	7 & half.	8 more	515	5 nearly	16 & half.
808	7 & half.	8	483	5 nearly	17
784	7 & half.	8 more	641	5 2	16

The reason why the heavy full balls fell in half the time of the hollow ones, was the resistance of the air: which resistance is very ingeniously and accurately assigned by Dr Wallis, in *Phil. Trans.* No. 186. And the cause of resistance of the fluids (as Sir Isaac Newton, *Opt. Q. 20.*) is partly from the friction of the parts of the fluid, partly from the inertia thereof. The resistance a spherical body meets with from friction, is as the right angle under the diameter, and the velocity of the moving body; and the resistance from the vis inertiae, is as the square of that product.

rotation round their own axes (*b*). The terraqueous globe particularly, which circumvolves at the rate of above 1000 miles an hour (*c*), would by the centrifugal force of that motion, be soon dissipated and spirited into the circumambient space, was it not kept together by this noble contrivance of the Creator, this natural inherent power, namely, the power of attraction or gravity.

And as by this power our globe is defended against dissipation, so all its parts are kept in their proper

For a farther account of the properties and proportions, etc. of gravity, in the fall or projection of bodies, I shall refer to the larger accounts of Galilaeus, Torricellius, Huygens, Sir Isaac Newton, etc. or to the shorter accounts of Dr Halley, in *Philos. Transf.* abridged by Mr Lowthorp, Vol. I. p. 561. or Dr Clarke, in his notes on Rohault, *Phys.* 2. c. 28. sect. 13. 16. And for the resistance of fluids, I refer to Dr Wallis before cited, and the *Ast. Erudit.* Lips. May 1693. where there is a way to find the force of mediums upon bodies of different figures.

(*b*) That the heavenly bodies move round their own axes, is beyond all doubt, manifest to our eye, in some of them, from the spots visible on them. The spots on the sun, easily visible with an ordinary glass, do manifest him to revolve round his own axis in about 25 days and a quarter. The spots on Jupiter and Mars prove those two planets to revolve also from east to west, as Dr Hook discovered in 1664, and 1665. And Venus also, although near the strong rays of the sun, hath, from some spots, been discovered by Mr Cassini, in 1666, and 1667, to have a manifest rotation. Vide Lowth. Abridg. vol. I. p. 382, and 423, 425. And such uniformity hath the Creator observed in the works of nature, that what is observable in one, is generally to be found in all others of the same kind. So that since it is manifest the sun, and three of his planets whirl round, it is very reasonable to conclude all the rest do so too; yea, every globe of the universe.

(*c*) The earth's circumference being 25,031 miles and a half, (according to hook II. chap. 2. note (*a*) p. 70.) if we divide that into 24 hours, we shall find the motion of the earth to be near 1043 miles in an hour. Which, by the by, is a far more reasonable and less rapid rate, than that of the sun would be, if we suppose the earth to stand still, and the sun to move round the earth. For according to the proportions in note (*c*) p. 58. of the preceding chapter, the circumference of the *Magnis Orbis* is 540,686,225 English miles, which divided by 24 hours, gives 22,528,364 miles in an hour. But what is this to the rapidity of the fixed stars, if we suppose them, not the earth, to move? Which is a good argument for the earth's motion.

place and order. All material things do naturally gravitate thereto, and unite themselves therewith, and so preserve its bulk entire (*d*). And the fleeting waters, the most unruly of all its parts, do by this means keep their constant aequipoise in the globe (*e*), and remain in that place which, the psalmist saith, 'God hath founded for them; a bound he hath set, which they might not pass; that they turn not again to cover the earth,' Psal. civ. 8. 9. So that, even in a natural way, by virtue of this excellent contrivance of the Creator, the observation of the psalmist is perpetually fulfilled, Psal. lxxxix. 9. 'Thou rulest the raging of the sea; when the waves thereof arise, thou stillest them.'

To these, and an hundred other uses of gravity, that I might have named, I shall only just mention another thing owing to it, and that is *levity* (*f*), that, whereby what we call light bodies swim, a thing no less useful to the world than its opposite, gravity, is, in many respects, to divers tribes of animals, but particularly serviceable to the raising up of vapours (*g*), and to their conveyance about the world.

(*d*) 'Nihil majus, quam quod ita stabilis est mundus, atque ita cohaeret ad permanendum, ut nihil ne excogitari quidem possit aptius. Omnes enim partes ejus undique medium locum capessentes, nituntur aequaliter: maxime autem corpora inter se juncta permanent, cum quodam quasi vinculo circumdata colligantur: quod facit ea natura, quae per omnem mundum omnia mente, et ratione conficiens, funditur, et ad medium rapit, et convertit extrema.' Cic. de Nat. Deor. l. ii. c. 45.

(*e*) 'Eadem ratione mare, cum supra terram sit, medium tamen terrae locum expetens, conglobatur undique aequaliter, neque redundat unquam, neque effunditur.' Id. paulo post.

(*f*) That there is no such thing as positive levity, but that levity is only a less gravity, is abundantly manifested by the acute Seign. Alph. Borelli de Mot. a Grav. pend. cap. iv. See also the annotations of the learned and ingenious Dr Clarke, on Rohault's Phys. p. 1. c. 16. Note 3. Also the experiments of the Acad. del. Cimento, p. 118, etc. Dr Wallis's Discourse of Gravity and Gravitation before the Royal Society, Nov. 12. 1674 p. 28, etc.

(*g*) I have before in note (*a*), chap. 3. page 50. shewn what vapours are, and how they are raised. That which I shall here

And now from this transient view of no other than the out-works, than the bare appendages of the terraqueous globe, we have so manifest a sample of the wisdom, power, and goodness of the infinite Creator, that it is easy to imagine the whole fabric is of a piece, the work of at least a skilful artist. A man that should meet with a palace (*b*) beset with pleasant gardens, adorned with stately avenues, furnished with well-contrived aqueducts, cascades, and all other appendages conducing to convenience or pleasure, would easily imagine, that proportionable architecture and magnificence were within; but we should conclude the man was out of his wits that should assert and plead, that all was the work of chance, or other than of some wise and skilful hand. And so when we survey the bare out-works of this our globe, when we see so vast a body, accoutred with so noble a furniture of air, light, and gravity; with every

note, is their quantity: concerning which, the before commended D. Halley hath given us some curious experiments in our Philos. Transact. which may be met with together in Mr Lowthorp's Abridg. vol. II. p. 108, and 126. Mr Sedileau also at Paris observed it for near three years. By all their observations it appears, that in the winter months the evaporations are least, and greatest in summer, and most of all in windy weather. And by Monsr. Sedileau's observations it appears, that what is raised in vapours, exceeds that which falleth in rain. In the seven last months of the year 1688, the evaporations amounted to 22 inches 5 lines; but the rain only 10 inches 6 lines one third: in 1689, the evaporations were 32 inches 10 lines and a half; but the rain 18 inches 1 line: in 1690, the evaporations 32 inches 11 lines; the rain 21 inches one third of a line. Vide Memb. de Matth. Phys. An. 1692. p. 25.

If it be demanded, what becomes of the overplus of exhalations that descend not in rain? I answer, they are partly tumbled down and spent by the winds, and partly descend in dews, which amount to a greater quantity than is commonly imagined. Dr Halley found the descent of vapours in dews so prodigious at St Helena, that he makes no doubt to attribute the origin of fountains thereto. And I myself have seen in a still, cool evening, large thick clouds hanging, without any motion, in the air, which in two or three hours time have been melted down by degrees, by the cold of the evening, so that not any the least remains of them have been left.

(*b*) See book II. chap. 3. note (*d*) p. 74.

things, in short, that is necessary to the preservation and security of the globe itself, or that conduceth to the life, health, and happiness, to the propagation and increase of all the prodigious variety of creatures the globe is stocked with; when we see nothing wanting, nothing redundant or frivolous, nothing botching or ill made, but that every thing, even in the very appendages alone, exactly answereth all its ends and occasions: what else can be concluded, but that all was made with manifest design, and that all the whole structure is the work of some intelligent Being; some Artist, of power and skill equivalent to such a work?

B O O K II.

Of the Terraqueous Globe itself in general.

IN the foregoing book having dispatched the out-works, let us take a survey of the principal fabric, *viz.* the terraqueous globe itself; a most stupendous work in every particular of it, which doth no less aggrandize its Maker (*a*), than every curious, complete work doth its workman. Let us cast our

(*a*) 'Licet—oculis quodammodo contemplari pulchritudinem earum rerum, quas divina providentia dicimus constitutas. Ac principio terra universa cernatur, locata in media mundi sede, solida, et globosa—vestita floribus, herbis, arboribus, frugibus. Quorum omnium incredibilis multitudo, insatiabili varietate distinguitur. Adde huc fontium gelidas perennitates, liquores perlucidos amnium, riparum vestitus viridissimos, speculuncarum concavas altitudines, saxorum asperitates, impendentium montium altitudines, immensitatesque camporum: adde etiam reconditas auri—venas—quae vero, et quam varia genera bestiarum?—qui volucrum lapsus, atque cantus? qui pecudum pastus?—quid de hominum genere dicam? qui quasi cultores terrae constituti, etc.—quae si, ut animis, sic oculis videre possemus, nemo cunctam intuens terram, de divina ratione dubitaret.' Cic. de Nat. Deor. l. 2. c. 39.

eyes here and there, let us ransack all the globe, let us, with the greatest accuracy, inspect every part thereof, search out the inmost secrets of any of the creatures; let us examine them with all our gauges, measure them with our nicest rules, pry into them with our microscopes, and most exquisite instruments (*b*), still we find them to bear testimony to their infinite Workman; and that they exceed all human skill so far, as that the most exquisite copies and imitations of the best artists are no other than rude bungling pieces to them. And so far are we from being able to espy any defect or fault in them, that the better we know them, the more we admire them; and the farther we see into them, the more exquisite we find them to be. And for a demonstration of this, I shall,

I. Take a general prospect of the terraqueous globe.

II. Survey its particulars.

I. The things which will fall under a general prospect of the globe, will be its figure, bulk, motion, place, distribution into the earth and waters, and the great variety of all things upon it and in it.

CH A P. I.

Of the FIGURE of the Terraqueous Globe.

THIS I suppose I may take for granted to be spherical, or nearly so (*a*). And this must

(*b*) 'I cannot here omit the observations that have been made in these later times, since we have had the use and improvement of the microscope, concerning the great difference, which by the help of that, doth appear betwixt natural and artificial things. Whatever is natural, doth by that appear adorned with all imaginable elegance and beauty — Whereas the most curious works of art, the sharpest, finest needle doth appear as a blunt, rough bar of iron, coming from the furnace, or the forge. The most accurate engravings or embossments seem such rude, bungling, deformed works, as if they had been done with a mattoe or a trowel. So vast a difference is there betwixt the skill of nature, and the rudeness and imperfections of art.' Bishop Wilk. Nat. Rel. l. i. ch. 6.

(*a*) Although the terraqueous globe be of an orbicular figure,

be allowed to be the most commodious, apt figure for a world on many accounts; as it is most capacious, as its surface is equi-distant from the centre, not only of the globe, but at least (nearly) of gravity and mo-

yet it is not strictly so. 1. On account of its hills and valleys. But these are inconsiderable to the earth's semidiameter; for they are but as the dust upon a common globe. But, 2. Our modern Astronomers assign a much greater variation from a globous form, namely, that of a prolate spheroid, making the polar about 34 miles shorter than the equatorial diameter. The cause of which they make to be the centrifugal force of the diurnal rotation of the globe.

This figure they imagine is in Jupiter, his polar being to his equatorial diameter, as 39 three fifths to 40 three fifths. But whether it be so or no, I confess I could never perceive, although I have often viewed that planet through very good and long glasses, particularly a tolerable good one of 72 feet in my hands: and although by reason of cloudy weather, and, at present, Jupiter's proximity to the sun, I have not been of late able to take a review of that planet; yet Saturn, so far as his ring would permit, and Mars, appear perfectly round, through Mr Huygens's long glass of 126 feet, which by will he bequeathed, with its whole apparatus, to our Royal Society, by whose favour it is now in my hands. And, moreover, I believe it difficult, next to impossible, to measure the two diameters to a 40th part, by reason of the smallness of Jupiter's apparent diameter, and by reason he is moving all the time of measuring him.

As to what is alledged from lengthening the pendulums of clocks, to make them keep the same time under the equator, as they do in our climes; I have shewn, from the like variations in the air-pump, that this may arise from the rarity of the air there, more than here. Vide Phil. Trans. No. 294. But if the degrees of a meridian grow larger, the more we go towards the line (as Mr Cassini affirms they do, by an 800th part in every degree, in Phil. Trans. No. 278.) then there is great reason to conclude in behalf of this spheroidal form.

The natural cause of this sphericity of our globe, is (according to Sir Isaac Newton's principles) that attraction, which the infinite Creator hath stamped on all the matter of the universe, whereby all bodies, and all the parts of bodies, mutually attract themselves, and one another. By which means, as all the parts of bodies tend naturally to their centre, so they all betake themselves to a globous figure, unless some other more prevalent cause interpose. Thus, drops of quick-silver put on a spherical form, the parts thereof strongly attracting one another. So drops of water have the same form, when falling in the air; but are hemisphere only when they lie on a hard body, by reason their gravity doth so far over-power their self-attracting power, as to take off one half of their sphericity. This figure is commonly at-

tion too, and, as some have thought, of the central heat and waters. But these, and divers other things, I shall pass over, and insist only upon two or three other benefits of this globous figure of the earth and waters.

1. This figure is the most commodious in regard of heat; and, I may add, of light also in some measure. For, by this means, those two great benefits are uniformly and equally imparted to the world: they come harmoniously and gradually on, and as gradually go off again. So that the daily and yearly returns of light and darkness, cold and heat, moist and dry, are regular and workman-like, we may say, which they would not be, especially the former, if the mass of earth and waters were, as some fancied it (*b*), a large plain; or, as others, like a large hill in the midst of the ocean; or of a multangular figure; or such like.

2. This figure is admirably adapted to the commodious and equal distribution of the waters in the globe. For since, by the laws of gravity, the waters will possess the lowest place; therefore, if the mass of the earth was cubic, prismatic, or any other angular figure, it would follow, that one, too vast a part, would be drowned; and another be too dry. But being thus orbicular, the waters are equally and commodiously distributed here and there, according as the divine providence saw most fit; of which I shall take notice by and by.

tributed to the pressure of the circumambient air: but that this cannot be the cause, is manifest from the air-pump; the case being the very same in an exhausted receiver, as in the open air, and not any the least alteration of the figure that I could perceive in all the trials I have made.

(*b*) It would be frivolous, as well as endless, to reckon up the various opinions of the ancients about the figure of the terraqueous globe; some of them may be seen in Varen. Geogr. l. 1. c. 1. init. or Johnston's Thaum. c. 1. artic. 3. But among the variety of opinions, one of the principal was, that the visible horizon was the bounds of the earth, and the ocean the bounds of the horizon, that the heavens and earth above this ocean, was the whole

3. The orbicular figure of our globe is far the most beneficial to the winds and motions of the atmosphere. It is not to be doubted, if the earth was of some other, or indeed any other figure, but that the currents of air would be much retarded, if not wholly stopped. We find by experience, what influence large and high mountains, bays, capes, and headlands have upon the winds; how they stop some, retard many, and divert and change, near the shores, even the general and constant winds (*c*), that blow round the globe in the torrid zone. And therefore, since this is the effect of such little excrescences, which have but little proportion to our globe, what would be the consequences of much vaster angles, which would equal a quarter, tenth, or but an hundredth part of the globe's radius? Certainly these must be such a barricade, as would greatly annoy, or ra-

isable universe; and that all beneath the ocean was Hades, the invisible world. Hence, when the sun set, he was said *tingere se oceano*; and when any went to Hades, they must first pass the ocean. Of this opinion were not only the ancient poets, and others among the Heathens, but some of the Christian fathers too, particularly Lactantius, St Augustine, and others, who thought their opinion was favoured by the psalmist, in Psal. xiv. 2. and cxxxvi. 6. See bishop Usher's answer to a Jes. Chall. 366. etc.

(*c*) 'Neither do these constant trade-winds usually blow near the shore, but only on the ocean, at least 30 or 40 leagues off at sea, clear from any land; especially on the west coast, or side of any continent: for indeed on the east side, the easterly wind being the true trade-wind, blows almost home to the shore, so near as to receive a check from the land wind.' Dampier's *Winds*, ch. 1.

And not only the general trade-winds, but also the constant shifting trade-winds, are, in like manner, affected by the lands. Thus, for instance, on the coast of Angola and Peru. But this, with the curious captain Dampier, the reader must take notice of, That the trade-winds that blow on any coast, except the north coast of Africa, whether they are constant, and blow all the year, or whether they are shifting winds, do never blow right in on the shore, nor right along shore, but go slanting, making an acute angle of about 23 degrees. Therefore, as the land extends more east or west, from north or south on the coast; so the winds do alter accordingly.' *Ibid.* ch. 2.

ther absolutely stop, the currents of the atmosphere, and thereby deprive the world of those salutiferous gales that I have said keep it sweet and clean.

Thus the figure of our globe doth manifest it to be a work of contrivance, in as much as it is of the most commodious figure; and all others would be liable to great and evident inconveniences.

CH A P. II.

Of the BULK of the Terraqueous Globe.

THE next thing remarkable in the terraqueous globe, is the prodigious bulk thereof (*a*). A mass of above 260 thousand million of miles solid content. A work too grand for any thing less than a God to make. To which, in the next place we may add,

CH A P. III.

The MOTIONS of the Terraqueous Globe.

THE motions the terraqueous globe hath, are round its own axis, and round its fountain of light and heat, the sun (*b*). That so vast a body as

(*a*) It is not difficult to make a pretty near computation of the bulk of the terraqueous globe, from those accurate observations of a degree made by Mr Norwood in England, and Mr Picard and Mr Cassini in France, whose measures do in a surprising manner agree. But Mr Cassini's seeming to be the most accurate, (as I have shewn in my *Astro-Theology*, book 1. chap. 2. note *a*), I have therefore made use of his determinations. According to which, the diameter of the earth being 7967.7 English miles, its ambit will be 25,031 miles and half; and, supposing it to be spherical, its surface will be 199,444,220 miles; which being multiplied into one third of its semidiameter, gives the solid content, viz. 264,856,000,000 miles.

(*b*) With the Copernicans, I take it here for granted, that the

the earth and waters should be moved at all (c), that it should undergo two such different motions, as the diurnal and annual are, and that these motions should be so constantly and regularly (d) performed for near 6000 years, without any the least alteration ever heard of, (except some hours which we read of in Josh. x. 2. 13. and in Hezekiah's time, which, if they cannot be accounted for some other way, do greatly increase the wonder (e); these things, I say), do

diurnal and annual revolutions are the motions of the terraqueous globe, not of the sun, etc.: but for the proof thereof I shall refer the reader to the preface of my Astro-Theology, and book iv. chap. 3.

(c) 'Every thing that is moved, must of necessity be moved by something else; and that thing is moved by something that is moved either by another thing, or not by another thing. If it be moved by that which is moved by another, we must of necessity come to some prime mover, that is not moved by another. For it is impossible, that what moveth, and is moved by another, should proceed in infinitum.' Arist. Phys. l. 8. c. 5. 'Solum quod seipsum movet, quod nunquam deseritur a se, nunquam ne moveri quidem desinit: quinetiam caeteris quae moventur, hic fons, hoc principium est movendi. Principii autem nulla est origo: nam ex principio oriuntur omnia; ipsum autem nulla ex re alia nasci potest: nec enim esset id principium, quod gigneretur aliunde.' Cic. Tusc. Quaest. l. 1. c. 23. 'Cogitemus qui fieri possit, ut tanta magnitudo, ab aliqua possit natura, tanto tempore circumferri? Ego igitur assero Deum causam esse, nec aliter posse fieri.' Plato in Epinom.

(d) Among the causes which Cleanthes is said in Tully to assign for man's belief of a Deity, one of the chief is, 'Acquabilitatem motus, conversionem coeli, solis, lunae, siderumque omnium distinctionem, varietatem, pulchritudinem, ordinem: quarum rerum aspectus ipse satis indicaret, non esse ea fortuita. Ut si quis in domum aliquam, aut in gymnasium, aut in forum venerit; cum videat omnium rerum rationem, modum disciplinam, non possit ea sine causa fieri judicare, sed esse aliquem intelligat, qui praesit, et cui pareatur: multo magis in tantis motibus, tantisque vicissitudinibus, tam multarum rerum atque tantarum ordinibus, in quibus nihil unquam immensa et infinita vetustas mentita sit, statuatur necesse est ab aliqua mente tantos naturae motus gubernari.' Cic. de Nat. Deor. l. 2. c. 5.

'Homines coeperunt Deum agnoscere, cum viderent stellas, tantam concinnitatem efficere; ac dies, noctesque aestate, et hyeme, suos servare statos ortus, atque obitus.' Plut. de plac. r. c. 6.

(e) We need not be solicitous to elude the history of these

manifestly argue some divine infinite power to be concerned therein (*f*): but, especially, if to all this we add the wonderful convenience, yea, absolute necessity of these circumvolutions to the inhabitants, yea, all the products of the earth and waters. For to one of these we owe the comfortable changes of day and night; the one for business, the other for repose (*g*): the one for man, and most other animals to gather and provide food, habitation, and other necessities of life; the other to rest, refresh, and recruit their spirits (*h*), wasted with the labours of the day. To the

miracles, as if they were only poetical strains, as Maimonides, and some others, fancy Joshua's day to have been, viz. only an ordinary summer's day; but such as had the work of many days done in it; and therefore, by a poetical stretch made, as if the day had been lengthened by the sun standing still. But in the history they are seriously related, as real matters of fact, and with such circumstances as manifest them to have been miraculous works of the Almighty: and the prophet Habakkuk, iii. 11. mentions that of Joshua as such. And therefore, taking them to be miraculous perversions of the course of nature, instead of being objections, they are great arguments of the power of God: for, in Hezekiah's case, to wheel the earth itself backward, or by some extraordinary refractions, to bring the sun's shadow backward 10 degrees: or in Joshua's case, to stop the diurnal course of the globe for some hours, and then again give it the same motion; to do, I say, these things, required the same infinite power which at first gave the terraqueous globe its motion.

(*f*) *Nam cum dispositi quævissem foedera mundi,
Præscriptoque maris fines, annique meatus,
Et lucis, noctisque vices: tunc omnia rebar
Consilio firmata Dei, qui lege moveri
Sidera, qui fruges diverso tempore nasci,
Qui variam Phœben alieno jussert igne
Compleri, solemque suo; porrexerit undis
Littora; tellurem medio libraverat axe.*

Claudian in Rufin. L. 1. initio,

(*g*) 'Diei noctisque vicissitudo conservat animantes, tribuens aliud agendi tempus, aliud quiescendi. Sic undique omni ratione concluditur, mente, concilioque divino omnia in hoc mundo ad salutem omnium, conservationemque admirabiliter administrari.' Cic. de Nat. Deorum. l. 2. c. 53.

(*h*) The acute Dr Cheyne, in his ingenious Philos. Princ. of Natural Religion, among other uses of day and night, saith, the

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other of those motions we owe the seasons of summer and winter, spring and autumn, together with the beneficial influences and effects which these have on the bodies and state of animals, vegetables, and all other things, both in the torrid, temperate, and frigid zones.

CHAP. IV.

Of the PLACE and SITUATION of the Terraqueous Globe, in respect of the heavenly bodies.

ANother thing very considerable in our globe, is its place and situation at a due distance from the sun (*a*), its fountain of light and heat; and from its neighbouring planets of the solar system, and from the fixed stars. But these things I have spoken more largely of in my Survey of the Heavens (*b*), and therefore only barely mention them now, to insist more largely upon

CHAP. V.

The DISTRIBUTION of the Earth and Waters.

THE distribution of the waters, and the dry land, although it may seem rude and unde-

nigh is most proper for sleep; because when the sun is above the horizon, sleep is prejudicial, by reason the perspirations are then too great. Also that nutrition is mostly, if not altogether, performed in time of rest; the blood having too quick a motion in the day; for which reason, weak persons, children, etc. are nourished most, and recruit best by sleep.

(*a*) It is a manifest sign of the Creator's management and care, in placing the terraqueous globe at that very distance it is from the sun, and tempering our own bodies, and all other things, so duly to that distance. For, was the earth farther from the sun, the world would be starved and frozen with cold: and was it nigher, we should be burnt, at least the most combustible things would be so, and the world would be vexed with perpetual conflagrations. For we see that a few of the rays of the sun, even no more than what fall within the compass of half an inch or an inch in a burning-glass, will fire combustible bodies, even in our own climate.

(*b*) Astro-Theology, book vii chap. 7.

signed to a careless view, and is by some taxed as such (*a*), yet is admirably well adjusted to the uses and conveniencies of our world.

For, in the first place, the distribution is so well made, the earth and waters so handsomely, so workman-like laid, every where all the world over, that there is a just equipoise of the whole globe. The Northern balanceth the Southern Ocean, the Atlantic the Pacific Sea. The American dry land is a counterpoise to the European, Asiatic and African.

In the next place, the earth and the waters are so admirably well placed about in the globe, as to be helpful to one another, to minister to one another's uses. The great oceans, and the lesser seas and lakes, are so admirably well distributed throughout the globe (*b*), as to afford sufficient vapours (*c*) for clouds

(*a*) The most eminent author I have met with, that finds fault with the distribution of the earth and waters, and indeed with the whole present structure of the globe, is the learned and eloquent theorist, Dr Burnet, who frequently exclaims on this point. 'Tellus nostra, si totam simul complectamur, non est ordinata et venusta rerum compages—sed moles aggesta vario, incerto, que situ partium, nulla ordinis aut venustatis habita ratione.' Theor. Sacr. l. i. c. 7. 'Ecquis autem a Deo haec ita facta?' etc. ib. 'Quo autem Herculeo labore opus esset ad excavandam terram in tantum hiatus?—Si immediate a causa prima effectus fuisset hic alveus, aliquem saltem ordinem, mensuram, et proportionem notare voluisset in ipsius forma, et partium dispositione;—sed confusa omnia, etc. ib. c. 8. Tellus nostra cum exigua sit; est etiam rudis: et in illa exiguitate multa sunt superflua, multa inelegantia. Dimidiam terrae superficiem inundat oceanus; magna ex parte, ut mihi videtur, inutilis.' And then he goes on to shew how this part of the creation might be mended, ib. c. 10. All this is to me surprising from an author of great ingenuity, who seems, in his book, to have a just opinion of, and due veneration for God. But certainly such notions are very inconsistent with the belief of God's creating, especially his governing and ordering the world. But suppose the terraqueous globe was such a rude, confused, inconvenient mass, as he pretends, yet it is well enough for a sinful world. But besides, what others have long ago abundantly answered, the following survey will, I hope, sufficiently manifest it to be the work of a wise and beneficent, as well as omnipotent Creator.

(*b*) Some have objected against the distribution of the earth and waters, as if the waters occupied too large a part of the globe,

which they think would be of greater use, if it was dry land. But then they do not consider that this would deprive the world of a due quantity of vapours and rain. For if the cavities which contain the sea, and other waters, were deeper, although the waters were no less in quantity, only their surfaces narrower and lesser, the evaporations would be so much the less, inasmuch as those evaporations are made from the surface, and are consequently in proportion to the surface, not the depth, or quantity of water.

(c) I took notice before, in book I. chap. 5. note (a) p. 50. that the vapours constituting clouds and rain, are vesiculae of water detached by heat. The manner of which I conceive to be thus; heat being of an agile nature, or the lightest of all bodies, easily breaks loose from them; and if they are humid, in its passage carries along with it particles, or little cases of the water; which being lighter than air, are buoyed up thereby, and swim in it; until by knocking against one another, or being thickened by the cold, as in the note before cited, they are reduced into clouds and drops.

Having mentioned the manner how vapours are raised, and there being more room here than in the note before-cited, I shall, for the illustration of nature's process, take notice of three things observable to our purpose, in water over the fire. 1. That the evaporations are proportional to the heat ascending out of the water. A small heat throws off but few vapours, scarce visible: a greater heat, and ascending in greater quantities, carries off grosser, larger, and more numerous vesiculae, which we call a steam; and if the heat breaks through the water with such a fury, as to lacerate and lift up great quantities or bubbles of water, too heavy for the air to carry or buoy up, it causeth what we call boiling. And the particles of water thus mounted up by the heat, are visible sphaerules of water, if viewed with a microscope, as they swim about in a ray of the sun let into a dark room, with warm water underneath; where some of the vapours appear large, some smaller sphaerules, according, no doubt, to the larger and lesser quantities of heat blowing them up and carrying them off. 2. If these vapours be intercepted in their ascent by any context, especially cold body, as glass, marble, etc. they are thereby reduced into drops, and masses of water, like those of rain, etc. 3. These vapours in their ascent from the water, may be observed, in cold frosty weather, either to rise but a little above the water, and there to hang, or to glide on a little above its surface: or if the weather be very cold, after a little ascent, they may be seen to fall back again into the water; in their ascent and descent describing a curve somewhat like that of an arrow from a bow. But in a warmer air, and still, the vapours ascend more nimbly and copiously, mounting up aloft, till they are out of sight. But if the air be warm and windy too, the vapours are sooner carried out of sight, and make way for others. And accordingly I have often observed, that hot liquors, if not set too thin, and not frequently stirred, cool slower in the

and rains, to temperate the cold (*d*) of the northern frozen air, to cool and mitigate the heats (*e*) of the torrid zone, and to refresh the earth with fertile showers; yea, in some measure, to minister fresh waters to the fountains and rivers. Nay, so abundant is this great blessing, which the most indulgent Creator hath afforded us by means of this distribution of the waters I am speaking of, that there is more than a scanty, bare provision, or mere sufficiency; even a plenty, a surplussage of this useful creature of God, the fresh waters, afforded to the world; and they so well ordered, as not to drown the nations of the

greatest frosts, than in temperate weather, especially if windy. And it is manifest, by good experiments, that the evaporations are less at those times than these; less by far in the winter than the warmer months.

(*d*) As our northern islands are observed to be more temperate than our continents, (of which we had a notable instance in the great frost 1708-9, which Ireland and Scotland felt less of than most parts of Europe besides; of which see book iv. chap. 12. note (*c*)), so this temperature is owing to the warm vapours afforded chiefly by the sea, which, by the preceding note, must necessarily be warm, as they are vapours, or water inflated by heat.

The cause of this heat I take to be partly that of the sun, and partly subterraneous. That it is not wholly that of the sun, is manifest from vapours, being as much, or more copiously raised, when the sun-beams are weakest, as when strongest, there being greater rains and winds at the one time than the other. And that there is such a thing as subterraneous heat, (whether central, or from the meeting of mineral juices; or such as is congenial, or connatural to our globe, I have not time to inquire; but, I say, that such a thing is), is evident not only from the hot-baths, many fiery eruptions and explosions, etc. but also from the ordinary warmth of cellars and places under ground, which are not barely comparatively warm, but of sufficient heat to raise vapours also: as is manifest from the smoking of perennial fountains in frosty weather, and water drawn out of pumps and open wells at such a time. Yea, even animals themselves are sensible of it, as particularly moles, who dig before a thaw, and against some other alterations of the weather; excited, no doubt, thereunto by the same warm vapours arising in the earth; which animate them, as well as produce the succeeding changes of the weather.

(*e*) Besides the trade-winds, which serve to mitigate the excessive heats in the torrid zone, the clouds are a good screen against

earth, nor to stagnate, stink, and poison, or annoy them; but to be gently carried through convenient channels back again to their grand fountain (*f*) the

the scorching sun beams, especially when the sun passeth their zenith; at which time is their winter, or coolest season, by reason they have then most clouds and rain. For which service, that which Varenæ takes notice of, is a great providence of God, viz. 'Pleraque loca zonæ torridæ vicinum habent mare, ut India, insulæ Indicae, lingua Africae, Guinea, Brasilia, Peruvia, Mexicana, Hispania: pauca loca zonæ torridæ sunt Mediterania.' Varenii Geogr. l. 2. c. 26. prop. 10. sect. 7.

(*f*) That springs have their origin from the sea, and not from rains and vapours, among many other strong reasons, I conclude from the perennity of divers springs, which always afford the same quantity of water. Of this sort there are many to be found every where. But I shall, for an instance, single out one in the parish of Upminster, where I live, as being very proper for my purpose, and one that I have had better opportunities of making remarks upon above twenty years. This in the greatest droughts is little, if at all, diminished, that I could perceive by my eye, although the ponds all over the country, and an adjoining brook, have been dry for many months together; as particularly in the dry summer months of the year 1705. And in the wettest seasons, such as the summer and other months were, preceding the violent storm in November 1703, (Vide Philos. Trans. No. 289), I say, in such wet seasons, I have not observed any increment of its stream, excepting only from violent rains falling therein, or running down from the higher land into it; which discoloureth the waters oftentimes, and makes an increase of only a day's, or sometimes but a few hours continuance. But now, if this spring had its origin from rain and vapours, there would be an increase and decrease of the one, as there should happen to be of the other: as actually it is in such temporary springs as have undoubtedly their source from rain and vapours.

But besides this, another considerable thing in this Upminster spring, and thousands of others, is, that it breaks out of so inconsiderable an hillock, or eminence of ground, that can have no more influence in the condensation of the vapours, or stopping the clouds, (which the maintainers of this hypothesis suppose), than the lower lands about it have. By some critical observations I made with a very nice portable barometer, I found that my house stands between 80 and 90 feet higher than the low water-mark in the river of Thames, nearest me; and that part of the river being scarce thirty miles from the sea, I guess, (and am more confirmed from some later experiments I made nearer the sea), that we cannot be much above 100 feet above the sea. The spring I judge nearly level with, or but little higher than where my house stands; and the lands from whence it immediately issues, I guess about 15 or 20 feet higher than the spring; and

sea; and many of them through such large tracks of land, and to such prodigious distances, that it is a great wonder the fountains should be high enough (*g*), or the seas low enough, ever to afford so long a conveyance. Witness the Danube (*h*) and Wolga of Europe, the Nile (*i*), and the Niger (*k*) of Afric,

the lands above that, of no very remarkable height. And indeed, by actual measure, one of the highest hills I have met with in Essex, is but 163 feet high; (Vide Philos. Transf. No. 313. p. 16.) and I guess, by some very late experiments I made, neither that, nor any other land in Essex, to be above 400 feet above the sea. Now, what is so inconsiderable a rise of land to a perennial condensation of vapours, fit to maintain even so inconsiderable a fountain, as what I have mentioned is? or indeed the high-lands of the whole large county of Essex, to the maintaining of all its fountains and rivulets?

But I shall no farther prosecute this argument, but refer to the late learned, curious, and industrious Dr Plot's Tentamen Phil. de Orig. Font. in which he hath fully discussed this matter.

As to the manner how the waters are raised up into the mountains and higher lands, an easy and natural representation may be made of it, by putting a little heap of sand, ashes, or a little loaf of bread, etc. in a basin of water; where the sand will represent the dry land, or an island, and the basin of water the sea about it. And as the water in the basin riseth to, or near the top of the heap in it, so do the waters of the sea, lakes, etc. rise in the hills. Which case I take to be the same with the ascent of liquids in capillary tubes, or between contiguous planes, or in a tube filled with ashes: of which the industrious and complete artificer in air-pumps, Mr Hawksbee, hath given us some, not contemptible experiments, in his Phys. Mech. Exp. p. 139.

Among the many causes assigned for this ascent of liquors, there are two that bid the fairest for it, viz. the pressure of the atmosphere, and the Newtonian attraction. That it is not the former, appears from the experiments succeeding, as well, or better, in vacuo, than in the open air, the ascent being rather swifter in vacuo. This then being not the cause, I shall suppose the other is; but for the proof thereof I shall refer to some of our late English authors, especially some very late experiments made before our most famous Royal Society, which will be so well improved by some of that illustrious body, as to go near to put the matter out of doubt.

(*g*) See book iii. chap. 4.

(*h*) 'The Danube, in a sober account, performs a course of above 1500 miles, (i. e. in a strait line) from its rise to its fall' Bohun's Geogr. Dict.

(*i*) 'Tractus sc. longitudo [Nili] est milliarium circiter 630 Germ. five Ital. 2520, pro quibus ponere licet 3000 propter curvaturas.' Varen. Geogr. l. 1. c. 16. p. 27.

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the Ganges (*l*), and Euphrates of Asia, and the Amazons River (*m*), and Rio de la Plata of America, and many others which might be named; some of which are said to run above 5000 miles, and some no less than 6000 from their fountains to the sea. And indeed such prodigious conveyances of the waters make it manifest, that no accidental currents and alterations of the waters themselves, no art or power of man, nothing less than the Fiat of the Almighty, could ever have made, or found, so long and commodious declivities, and channels for the passage of the waters.

CHAP. VI.

The great VARIETY and QUANTITY of all THINGS upon, and in the Terraqueous Globe, provided for the Uses of the World.

THE last remark I shall make about the terra-queous globe in general is, the great variety of kinds, or tribes, as well as prodigious number of individuals of each various tribe, there is of all creatures (*a*). There are so many beasts, so many birds,

(*) Varenæ reckons the course of the Niger, at a middle computation, 600 German miles, that is 7400 Italian.

(*l*) That of the Ganges he computes at 300 German miles. But if we add the curvatures to these rivers, their channels are of a prodigious length.

(*m*) 'Oritur flumen (quod plerumque Amazonum, etc.) haud procul quito in montibus—Cum per leucas Hispanicas 1356. cursum ab occidente in orientem continuet, ostio 84 leucas lata—in oceanum præcipitatur.' Chr. D'Acugna relatio de flumine Amaz. in Act. Erud. Aug. 1683.

(*a*) 'Non dat Deus beneficia? Unde ergo ista quæ possides?—Unde hæc innumerabilia, oculos, aures et animum mulcentia? Unde illa luxuriam quoque instruens copia? Neque enim necessitatibus tantummodo nostris provisum est: usque in delicias amamur. Tot arbusta, non uno modo frugifera, tot herbae salutare, tot varietates ciborum, per totum annum digestæ, ut inertæ quoque sortita terras alimento præberent. Jam ani-

so many insects, so many reptiles, so many trees, so many plants upon the land; so many fishes, sea-plants, and other creatures in the waters; so many minerals, metals, and fossils in the subterraneous regions; so many species of these genera, so many individuals of those species, that there is nothing wanting to the use of man, or any other creature of this lower world. If every age doth change its food, its way of cloathing, its way of building; if every age (b) hath its variety of diseases; nay, if man, or any other animal, was minded to change these things every day, still the creation would not be exhausted, still nothing would be wanting for food, nothing for physic, nothing for building and habitation, nothing for cleanliness and refreshment, yea, even for recreation and pleasure. But the munificence of the Creator is such, that there is abundantly enough to supply the wants, the conveniencies, yea, almost the extravagancies of all the creatures, in all places, all ages, and upon all occasions.

And this may serve to answer an objection against the excellency of, and wisdom shewed in, the creation; namely, what need of so many creatures (c)?

* *malis omnis generis, alia in sicco, etc.—ut omnis rerum naturae pars tributum aliquod nobis conferret.* Senec. de Benef. l. 4. c. 5. ubi plura vide.

* *Hic, ubi habitamus, non intermittit suo tempore coelum nitescere, arbores frondescere—tum multitudinem pecudum partim ad vescendum, partim ad cultus agrorum, partim ad vehendum, partim ad corpora vestienda; hominemque ipsum quasi contemplatorem coeli ac deorum, ipsorumque cultorem.*
 * *—Haec igitur, et alia innumerabilia cum cernimus, possumusne dubitare, quin his praesit aliquis vel effector, si haec nata sunt, ut platoni videtur: vel si semper fuerint, ut Aristoteli placet, moderator tanti operis et muneris?* Cic. Tusc. Quael. l. 1. c. 28. 29.

(b) *Sunt et gentium differentiae non mediocres—quae contemplatio aufert rursus nos ad ipsorum animalium naturas, ingentitasque iis vel certiores morborum omnium medicinas. Enimvero rerum omnium parens, nullum animal ad hoc tantum ut pasceretur, aut alia satiare, nasci voluit: artesque salubres inseruerit.* Plin. Nat. Hist. l. 27. c. 13.

(c) This was no very easy question to be answered by such as

particularly of so many insects, so many plants, and so many other things? and especially of some of them, that are so far from being useful, that they are very noxious; some by their ferity, and others by their poisonous nature, etc.

To which I might answer, that in great variety, the greater art is seen; that the fierce, poisonous, and noxious creatures serve as rods and scourges to chastise us (*d*), as means to excite our wisdom, care, and industry, with more to the same purpose. But

held, that 'all things were made for man;' as most of the ancients did; as Aristotle, Seneca, Cicero, and Pliny, (to name only some of the chief). And Cicero cites it as the celebrated Chrysippus's opinion, 'Praeclare enim Chrysippus, caetera nata esse hominum causa, et deorum.' *De fin. bon. et mal.* l. 3. And in his *De Nat. Deor.* l. 2. fin. he seriously proves the world itself to have been made for the gods and men, and all things in the world to have been made and contrived for the benefit of man, 'parata et inventa ad fructum hominum,' are his words. So Pliny, in his preface to his 7th book, saith, Nature made all things for man; but then he makes a doubt, whether she shewed herself a more indulgent parent, or cruel step-mother, as in book iv. chap. 12. note 2. But since the works of God have been more discovered, and the limits of the universe have been found to be of infinitely greater extent than the ancients supposed them; this narrow opinion hath been exploded. And the answer will be found easy to these questions, why so many useless creatures? in the heavens, why so many fixed stars, and the greatest part of them scarce visible? why such systems of planets, as in Jupiter, Saturn, etc.? (See my *Astro-Theology*). In the earth and waters, why so many creatures of no use to man?

(*d*) 'Nec minus clara exitii documenta sunt etiam ex contemendis animalibus. M. Varro author est a cuniculis suffossus in Hispania oppidum; a talpis in Thessalia: ab ranis civitatem in Gallia pulsam, ab locustis in Africa: ex Gyaro Cycladum insula, incolas a muribus fugatos: in Italia Amyclas a serpentibus deletas. Citra Cynamolgos Æthiopas late deserta regio est, a scorpionibus et solpugis gente sublata: et a scolopendris abactos Trerienteses, auctor est Theophrastus.' *Plin. Nat. Hist.* l. 8. c. 29.

To these instances may be added, the plague they sometimes suffer from a kind of mice (they call Leming, Leminger, Lemmus, etc.) in Norway, which eat up every green thing. They come in such prodigious numbers, that they fancy them to fall from the clouds; but Ol. Magnus rather thinks they come from some of the islands, *Hist.* l. 8. c. 2. If the reader hath a mind to see a large account of them, with a dispute about their generation, a handsome eut of them, with the prayers, and an exor-

these things have been fully urged by others; and it is sufficient to say, that this great variety is a most wise provision for all the uses of the world in all ages,

cism against them used in the church of Rome, I shall refer him (it being too tedious to recite in these notes) to Musæum Wormian. l. 3. c. 23.

‘Quare patimur multa mala a creatura quam fecit Deus, nisi quia offendimus Deum?—De poena tua peccatum tuum accusa, non judicem. Nam propter superbiam instituit Deus creaturam istam minimam et abjectissimam ut ipsa nos torqueret, ut cum superbus fuerit homo, et se jactaverit adversus Deum,—cum se crexerit, pulicibus subdatur. Quid est, quod te inflas humana superbia?—Pulicibus resiste ut dormias. Cognosce qui sis. Nam propter superbiam nostram domandam—creata illa quæ molestia sunt: populum Pharaonis superbum potuit Deus domare de urtis, etc. Muscas et ranas illas immisit, ut rebus vilissimis superbia domaretur. Omnia ergo per ipsum—facta sunt; et sine ipso factum est nihil.’ Aug. Tract. 1. in S. Joh.

But although the infinitely wise Creator hath put it in the power of such vile animals to chastise us, yet hath he shewed no less wisdom and kindness in ordering many, if not most of them so, as that it shall be in the power of man, and other creatures, to obviate or escape their evils. For, besides the noble antidotes afforded by minerals, vegetables, etc. many, if not most of our European venomous animals carry their cure, as well as poison in their own bodies. The oil, and, I doubt not, the body of scorpions too, is a certain remedy against its stroke. A bee, wasp, &c. hornet, crushed and rubbed, and bound upon the place, I have always found to be a certain cure for the sting of those creatures. And I question not, but the flesh, especially the head, of vipers, would be found a remedy for their bites.

‘Our viper-catchers have a remedy, in which they place so great confidence, as to be no more afraid of the bite [of a viper] than of a common puncture, immediately curing themselves by the application of their specific. This though they keep a great secret, I have, upon strict inquiry, found to be no other than *Axungia Viperina*, presently rubbed into the wound.’ This remedy the learned doctor tried himself with good success, in a young dog that was bitten in the nose. Vide Mead of poisons, p. 29.

And as to the means to escape the mischief of such noxious animals, besides what may be effected by the care, industry, and sagacity of man; some of them are so contrived and made, as to give warning or time to creatures in danger from them. Thus, for instance, the rattle-snake, the most poisonous of any serpent, who darts its poisonous vapours to some distance, and in all probability was the basilisk of the ancients, said to kill with its eyes; this involuntarily gives warning by the rattle in its tail. So the shark, the most rapacious animal of the waters, is forced to turn himself on his back, and thereby gives an opportunity of escape, before he can catch his prey.

and all places: some for food, some for phyfic (e), some for habitation, some for utensils, some for tools and instruments of work, and some for recreation and pleasure, either to man, or to some of the inferior creatures themselves; even for which inferior creatures the liberal Creator hath provided all things necessary, or any ways conducing to their happy, comfortable living in this world, as well as for man.

And it is manifest, that all the creatures of God, beasts, birds, insects, plants, and every other genus, have, or may have, their several uses even among men. For although in one place many things may be neglected, and out of use, yet in other places they may be of great use. So what hath seemed useles in one age, hath been received in another; as all the new discoveries in phyfic, and all the alterations in diet do sufficiently witness. Many things also there are which in one form may be pernicious to man; but in another of great use. There are many plants (f),

(e) 'Haec sola naturae placuerat esse remedia parata vulgo, inventu facilia, ac sine impendio, ex quibus vivimus. Postea fraudes hominum et ingeniorum capturae officinas invenire istas, in quibus sua cuique homini venalis promittitur vita. Statim compositiones et misturae inexplicabiles decantantur. Arabia atque India in medio aestimantur, ulcerique parvo medicina a Rubro mari importatur, cum remedia vera quotidie pauperimus quisque coenat.' Plin. l. 24. c. 1.

'Non sponte sua ex tellure germinant herbae, quae contra quoscunque morbos accommodatae sunt; sed eae voluntate opificis, ad nostram utilitatem productae sunt.' Basil. Ascet. Tom.

Consult here book x. note (z), (aa), (bb).

(f) Among poisonous vegetables, none more famous of old than hemlock, accounted at this day also very dangerous to man, of which there are some dismal examples in our Philos. Trans. Pepser, etc. But yet this plant is food for goats, and its seeds for bustards; and, as Galen saith, to starlings also. Neither is it so pernicious a plant, only food, but also phyfic to some animals. An horse troubled with the farcy, and could not be cured with the most famous remedies, cured himself of it in a short time, by eating hemlock, of which he eat greedily. Vide Phil. Trans. No. 231. 'And a woman which was cured of the plague, but wanted sleep, did, with very good effect, eat hemlock for some time; till falling ill again of a fever, and having left off the use of this remedy, he [Nic. Fontanus] endeavour-

many animals, many minerals, which in one form destroy, in another heal. The cassada plant unprepared poisoneth, but prepared is the very bread of the West-Indies (g). Vipers and scorpions, and many minerals, as destructive as they are to man, yet afford him some of his best medicines.

Or if there be many things of little immediate use to man, in this, or any other age; yet to other creatures they may afford food or physic, or be of some necessary use. How many trees and plants, nay, even the very carcases of animals, yea, the very

‘ed to procure her rest by repeated doses of opium, which had no operation, till the help of cicuta was again called in with desired success.’ Mead of Pois. p. 144.

And not only hemloc, but many other, if not most plants accounted poisonous, may have their great use in medicine: of which take the opinion of a noble judge, my ingenious and learned friend, Dr Tancred Robinson, in a letter I have of his to the late great Mr Ray, of Nov. 7. 1664, viz. ‘According to my promise, I here send you a few observations concerning some plants seldom used in medicine, being esteemed poisonous, which if truly corrected, or exactly dosed, may perhaps prove the most powerful and effectual medicines yet known.’ Having then given an account of some of their correctives, he gives these following examples, viz. 1. ‘The hellebores incorporated with a sapo, or alkaly-salts alone, are successful remedies in epilepsies, vertigos, pallsies, lethargies, and manias. Dos. a ʒj. to 3 ʒ. 2. The Radic. Asari, Cicutae, and the Napellus, in agues and periodical pains. Dos. ʒj, 3 ʒ. 3. The Hyoscyamus in Haemorrhagies, violent heats and perturbation of the blood, and also in all great inflammations. Dos ʒj. to 3 ʒ. 4. The Semen Stramoniae is a very good anodyne, useful in vigilias, rheumatism, hysteric cases, in all the orgasms of the blood or spirits, and where-ever there is an indication for a perregoric. Dos. 3 j. to 3 ʒ. 5. Elaterium thus corrected, may be given from gr. x. to xv. in hydropical cases, without any sensible evacuation or disturbance. So may the Soldanella and Gratiola in greater doses. 6. Opium corrected as aforementioned, loses its narcotic faculty, and may be given very safely in great doses, and proves more than usually prevalent in convulsive cases, fluxes, catarrhs, and all painful paroxysms, etc. (g) ‘It is of the most general use of any provision all over the West-Indies, especially in the hotter parts, and is used to victual ships.’ Dr Sloan’s Nat. Hist. of Jamaica, vol. 1. ch. 9. sect. 12.

dust of the earth (*b*), and the most refuse, contemptible things to be met with; I say, how many such things are either food, or probably medicine to many creatures; afford them retreat, are places of habitation, or matrixes for their generation, as shall be shewed in proper place? The prodigious swarms of insects in the air, and in the waters, (many of which may be perhaps at present of no great use to man), yet are food to birds, fishes, reptiles, insects themselves, and other creatures (*i*), for whose happy and comfortable subsistence, I have said the bountiful Creator hath liberally provided, as well as for that of man.

B O O K III.

*Of the Terraqueous Globe in particular,
more especially the Earth.*

HAVING thus taken a general prospect of our terraqueous globe, I shall in this book come to its particulars. But here we have such an immense variety presenting itself to our senses, and such amazing strokes of power and wisdom, that it is impossible not to be at a stand, and very difficult to know where to begin, how to proceed, or where to end. But we must however attempt.

And for the more clear and regular proceeding on this copious subject, I shall distribute the globe into its own grand constituent parts.

(*b*) I have shewn, in the Phil. Transf. that the pediculus fatidicus, mortisaga, pulsatorius, or death-watch, there described, feedeth upon dust; but that this dust they eat, is powdered bread, fruits, or such like dust, not powdered earth; as is manifest from their great diligence and curiosity in hunting among the dust. See more in Phil. Transf. No. 291.

(*i*) See book iv. chap. 11.

I. The earth and its appurtenances.

II. The waters and theirs.

The first of these only, is what at present I shall be able to take into this survey.

And in surveying the earth, I intend,

1. To consider its constituent parts, or things peculiar to itself.

2. The inhabitants thereof, or the several kinds of creatures that have their habitation, growth, or subsistence thereon.

1. As to the earth itself, the most remarkable things that present themselves to our view, are,

1. Its various moulds and soils.

2. Its several strata, or beds.

3. Its very subterraneous passages, grottos, and caverns.

4. Its mountains and valleys.

CH A P. I.

Of the SOILS and MOULDS in the Earth.

THE various soils and moulds are an admirable and manifest contrivance of the all-wise Creator, in making this provision for the various vegetables (*a*), and divers other uses of the creatures.

(*a*) It is not to be doubted, that although vegetables delight in peculiar soils, yet they owe not their life and growth to the earth itself, but to some agreeable juices or salts, etc. residing in the earth. Of this the great Mr Boyle hath given us some good experiments. He ordered his gardener to dig up, and dry in an oven, some earth fit for the purpose, to weigh it, and to set therein some squash seeds, (a kind of Indian pompion). The seeds when sown were watered with rain or spring water only. But although a plant was produced in one experiment of near 3 lb. and in another of above 14 lb. yet the earth when dried, and weighed again, was scarce diminished at all in its weight.

Another experiment he alledges is of Helmont's, who dried 200 lb. of earth, and therein planted a willow weighing 5 lb. which he watered with rain, or distilled water: and to secure it

For, as some trees, some plants, some grains dwindle and die in a disagreeable soil, but thrive and flourish in others; so the all-wise Creator hath amply provided for every kind a proper bed.

If some delight in a warm, some in a cold soil; some in a lax or sandy, some a heavy or clayey soil; some in a mixture of both, some in this, and that, and the other mould, some in moist, some in dry places (b); still we find provision enough for all these purposes: every country abounding with its proper trees and plants (c), and every vegetable flourishing and gay, somewhere or other about the globe, and abundantly answering the almighty command of the Creator, when the earth and waters were ordered to their peculiar place, Gen. i. 11. 'And God said, Let the earth bring forth grass, the herb yielding seed, and the tree yielding fruit after his kind.' All which we actually see is so.

To this convenience which the various soils that coat the earth are of to the vegetables, we may add their great use and benefit to divers animals, to many

from any other earth getting in, he covered it with a perforated tin cover. After five years, weighing the tree with all the leaves it had borne in that time, he found it to weigh 169 lb. 3 3/4; but the earth to be diminished only about 2 3/4 in its weight. Vid. Boyle's Scept. Chym. part 2. page 114.

(b) Τὺς δὲ τόπους ζητῶ τὺς οἰκίους, ὃ μόνον τὰ περιττά---Τῶν δένδρων, &c. Τὰ μὲν γὰρ φιλῶ ξηρὺς, τὰ δὲ ἐνυδρὺς, τὰ δὲ χειμερινὺς, τὰ δὲ προσήλως, τὰ δὲ παλισκίους, ὃ ὅλως, τὰ μὲν ὀρενὺς τὰ δὲ ἐλωδεις---Ζητῶ γὰρ τὰ πρόσφορα κατὰ τὴν κρᾶσιν, ἔτι δὲ ἀσθενῇ, ὃ ἰσχυρά, ὃ βαθύρριζα, ὃ ἐπιπολαιόρριζα, ὃ ἔτις ἄλλη διαφορά, κατὰ τὰ μέρη---Πάντα γὰρ αὐτὰ, ἔτι δὲ τὰ ὅμοια ζητῶ τὸ ὅμοιον, ὃ τὰ ἀνόμοια μὴ τὸν αὐτὸν, τὰν ἢ τις παραλλαγὴ τῆς φύσεως. Theophrast. de. Caus. Plant. l. 2.

(c) Nec vero terrae ferre omnes omnia possunt.
Fluminibus Salices, crassisque paludibus Alni
Nascuntur: steriles saxosis montibus Orni:
Littora Myrtetis laetissima: denique apertos
Bacebus amat colles: Aquilonem et frigora Taxi.
Aspice et extremis domitum cultoribus orbem,
Eoasque domos Arabum, pictosque Geonos:
Divisae arboribus patriae, etc. Virg. Georg. l. 2.

kinds of quadrupeds, fowls, insects, and reptiles, who make in the earth their places of repose and rest; their retreat in winter, their security from their enemies, and their nests to repose their young; some delighting in a lax and pervious mould, admitting them an easy passage; and others delighting in a firmer and more solid earth, that will better secure them against injuries from without.

CH A P. II.

Of the various STRATA, or BEDS, observable in the Earth.

THE various Strata, or Beds, although but little different from the last, yet will deserve a distinct consideration.

By the Strata, or Beds, I mean those layers of minerals (*a*), metals (*b*), earth and stone (*c*), lying

(*a*) Although minerals, metals, and stones lie in beds, and have done so ever since Noah's flood, if not from the creation; yet it is greatly probable, that they have power of growing in their respective beds: that as the beds are robbed and emptied by miners, so after a while they recruit again. Thus vitriol, Mr Boyle thinks, will grow by the help of the air. So allum doth the same. 'We are assured (he saith) by the experienced Agricola, that the earth, or ore of allum, being robbed of its salt, will in track of time recover it, by being exposed to the air.' Boyl. Susp. about some hid. Qual. in the Air, p. 18.

(*b*) As to the growth of metal, there is great reason to suspect that also, from what Mr Boyle hath alledged in his Observations about the growth of Metals; and in his Scept. Chym. part 6. p. 362. Compare also Hakewill's Apol. p. 164.

And particularly as to the growth of iron, to the instances he gives from Pliny, Fallopius Caesalpinus, and others; we may add, what is well known in the forest of Dean in Gloucestershire; that the best iron, and most in quantity, that is found there, is in the old cinders, which they melt over again. This the author of the Additions to Gloucestershire, in Camden's Brit. of the last edition, p. 245. attributes to the remissness of the former melters, in not exhausting the ore: but in all probability, it is rather to be attributed to the new impregnations of the old ore, or cinders, from the air, or from some seminal principle, or plastic quality in the ore itself.

(*c*) As for the growth of stone, Mr Boyle gives two instances

under that upper stratum, or tegument of the earth last spoken of, all of a prodigious use to mankind: some being of great use for building; some serving for ornament; some furnishing us with commodious machines, and tools to prepare our food, and for vessels and utensils, and for multitudes of other uses; some serving for firing to dress our food, and to guard us against the insults of cold and weather; some being of great use in physic, in exchange and commerce, in manuring and fertilizing our lands, in dying and colouring, and ten thousand other conveniences, too many to be particularly spoken of: only there is one grand use of one of these strata, or beds, that cannot easily be omitted, and that is, those subterraneous strata of sand, gravel, and laxer earth

one is that famous place in France, called Les Cayes Coutieres:

Where the water, falling from the upper parts of the cave to the ground, doth presently there condense into little stones, of such figure as the drops, falling either severally, or upon one another, and coagulating presently into stones, chance to exhibit. Nid. Scept. Chym. p. 360.

Such like caves as these I have myself met with in England; particularly on the very top of Bredon Hill in Worcestershire, near the precipice, facing Pershore, in or near the old fortress, called Bembsbury-Camp; I saw some years ago such a cave, which, if I misremember not, was lined with those stalactical-stones on the top and sides. On the top they hung like icicles great and small, and many lay on the ground. They seemed manifestly to be made by an exudation or extillation of some petrifying juices out of the rocky earth there. On the spot, I thought it might be from the rains soaking through, and carrying with it impregnations from the stone, the hill being there all rocky. Hard by the cave is one or more vast stones, which, if I mistake not, are incrustated with this sparry, stalactical substance, if not wholly made of it. But it is so many years ago since I was at the place, and not being able to find many notes about it, I cannot say whether the whole stone is, in all probability, spar, as I think it is, or whether I found it only cased over with it, notwithstanding I was very nice in examining it then, and have now some of the fragments by me, consisting, among other shining parts, of some transparent angular ones.

The other instance of Mr Boyle, is from Linschoten, who hath, that in the East-Indies, when they have cleared the diamond-mines of all the diamonds, 'In a few years time they find in the same place new diamonds produced.' Boyle, *ibid.*

that admit of, and facilitate the passage of the sweet waters (*d*), and may probably be the colanders whereby they are sweetened, and then at the same time also conveyed to all parts of the habitable world, not only through the temperate and torrid zones, but even the farthest regions of the frozen poles.

That these strata are the principal passages of the sweet fountain-waters, is, I think, not to be doubted, considering that in them the waters are well known to pass, and in them the springs are found by those that seek for them: I say, the principal passages, because there are other subterraneous guts and channels, fissures and passages, through which many times the waters make their way.

Now that which in a particular manner doth seem to me to manifest a special providence of God in the

(*d*) It is not only agreeable to reason, but I am told by persons conversant in digging of wells throughout this county of Essex, where I live, that the surest beds in which they find water, are gravel, and a coarse dark coloured sand; which beds seldom fail to yield plenty of sweet water: but for clay, they never find water therein, if it be a strong, stiff clay; but if it be lax and sandy, sometimes springs are found in it; yet so weak, that they will scarcely serve the uses of the smallest family. And sometimes they meet with those beds lying next, under a loose, black mould, (which, by their description, I judged to be a sort of oazy, or to have the resemblance of an ancient, rusty ground), and in that case the water is always naught, and stinks. And lastly, another sort of bed they find in Essex, in the clayey lands, particularly that part called the Rodings, which yields plenty of sweet water, and that is a bed of white earth, as though made of chalk and white sand. This they find, after they have dug through forty, or more, feet of clay; and it is so tender and moist, that it will not lie upon the spade, but they are forced to throw it into their bucket with their hands, or with bowls; but when it comes up into the air, it soon becomes an hard white stone.

Thus much for the variety of beds wherein the waters are found. That it is in these beds only or chiefly the springs run, is farther manifest from the forcible eruption of the waters sometimes out of those watery beds. Of which see chap. 4. note (*B*). This eruption shews, that the waters come from some eminence or other, lying at a distance, and being closely pent up within the watery stratum, by the clayey strata, the waters with force mount up, when the strata above are opened,

repositing these watery beds is, that they should be dispersed all the world over, into all countries, and almost all tracks of land: that they should so entirely, or for the most part, consist of lax, incohering earth, and be so seldom blended with other impervious moulds, or if they are so, it is commonly but accidentally; and that they are interposed between the other impervious beds, and so are as a prop and pillar to guard them off, and to prevent their sinking in and shutting up the passages of the waters.

The time when those strata were laid, was doubtless at the creation, when 'God said, (Gen. i. 9.) Let the waters under the heavens be gathered together unto one place, and let the dry land appear;' or else at the deluge, if, with some sagacious naturalists, we suppose the globe of earth to have been dissolved by the flood (*e*). At that time, whatever it was, when the terraqueous globe was in a chaotic state, and the earthly particles subsided, then those several beds were, in all probability, repositied in the earth, in that commodious order in which they now are found, and that, as is asserted, according to the laws of gravity (*f*).

(*e*) Vide Dr Woodward's Essay, part 2. Steno's Prodr. etc.

(*f*) Id. ib. p. 28. and 74. But Dr Leigh, in his Nat. History of Lancashire, speaking of the coal-pits, denies the strata to lie according to the laws of gravitation, saying, the strata are a bed of marle, afterwards free-stone, next iron-stone, then coal or kennel-mine, then some other strata, and again coal, etc.

But upon a stricter inquiry into the matter, finding I had reason to suspect that few, if any, actually had tried the experiment, I was minded to bring the thing to the test of experiment myself; and having an opportunity, on April 11. 1712. I caused divers places to be bored, laying the several strata by themselves; which afterwards I weighed with all strictness, first in air, then in water, taking care that no air-bubbles, etc. might obstruct the accuracy of the experiment. The result was, that in my yard, the strata were gradually specifically heavier and heavier, the lower and lower they went; and the upper, which was clay, was considerably specifically lighter than the lower stratum; which was first a loose sand, then a gravel. In which stratum principally the springs run that supply my well.

But in my fields, where three places were bored, to no great

C H A P. III.

Of the Subterraneous CAVERNS and the VULCANOS.

I Shall take notice of the subterraneous caverns, grottos, and vulcanos, because they are made an objection (*a*) against the present contrivance and structure of the globe. But, if well considered, they will be found to be wise contrivances of the Creator, serving to great uses of the globe, and ends of God's government. Besides many secret, grand functions and operations of nature in the bowels of the earth, that in all probability these things may minister unto, they are of great use to the countries where they are (*b*). To instance in the very worst of the things named, viz. the vulcanos and ignivomous mountains; although they are some of the most terrible shocks of the globe, and dreadful scourges of the sin-

depth, I found below the upper (superficial stratum) a deep bed of sand only, which was of different colours and consistence, which I weighed as before, together with the virgin-mould; but they were all of the same, or nearly the same specific gravity, both out of the same hole, and out of different holes, although the sand was at last so gravelly, that it hindered our boring any deeper.

Upon this, fearing lest some error might be in the former experiments, I tried them over again; and that with the same success.

After this I made some experiments in some deep chalk pits, with the flints, chalk, etc. above and below; but the success was not so uniform as before.

Acquainting our justly renowned Royal Society with these experiments, they ordered their operator to experiment the strata of a coal-pit; the success whereof may be seen in Phil. Trans. No. 336.

(*a*) 'Nemo dixerit terram pulchriorem esse quod cavernosa sit, quod dehiscat in multis locis, quod disrupta caveis et spatiis inanis; iisque nullo ordine dispositis, nulla forma: nec quod aliud contineant quam tenebras et sordes; unde graves et pestiferæ exhalationes, terræ motus,' etc. Burn. ubi sup. c. 7.

(*b*) The Zirchnitzer sea, in Carneola, is of great use to the

ful inhabitants thereof, and may serve them as emblems, and presages of hell itself; yet even these have their great uses too, being as spiracles or tunnels (c) to the countries where they are, to vent the fire and vapours that would make dismal havoc, and oftentimes actually do so, by dreadful succussions and convulsions of the earth. Nay, if the hypothesis of a central fire and waters be true, these outlets seem to be of greatest use to the peace and quiet of the terraqueous globe, in venting the subterraneous heat and vapours; which, if pent up, would make dreadful and dangerous commotions of the earth and waters.

It may be then accounted as a special favour of the divine providence, as is observed by the author before praised (d), 'That there are scarcely any countries, that are much annoyed with earthquakes, that have not one of these fiery vents. And these (saith he) are constantly all in flames whenever any earthquake happens, they disgorging that fire, which whilst underneath, was the cause of the disaster. Indeed (saith he) were it not for these diverticula, whereby it thus gaineth an exit, it would rage in the bowels of the earth much more furiously-

inhabitants of that country, by affording them fish, fowls, fodder, seeds, deer, swine, and other beasts, carriage for their goods, etc. Vide Phil. Transf. No. 191, etc. or Lowth. Abrig. vol. 2. p. 306, etc. where you have put together in one view, what is dispersed in divers of the transactions. This sea or lake proceeds from some subterraneous grotto, or lake, as is made highly probable by Mr Valvasor, *ibid*.

The grotto Podpetschio may be another instance, that the very subterraneous lakes may be of use, even to the inhabitants of the surface above: of which see Lowth. *ubi supra*, p. 317. Sturmius also may be consulted here in his *Phil. Eccl. Exer.* 11. de *Terrae mot.* particularly in chap. 3. some of the most eminent specus's are enumerated, and some of their uses.

(c) 'Crebri specus [remedium] praebent. Praeconceptum enim spiritum exhalant: quod in certis notatur oppidis, quae minus quatiantur, crebris ad eluviem cuniculis cavata.' Plin. *Hist. Nat.* l. 2, c. 82.

(d) Woodward's Essay, par. 3. cons. 13

‘ly, and make greater havoc than now it doth. So
 ‘that, though those countries, where there are such
 ‘vulcanos, are usually more or less troubled with
 ‘earthquakes; yet, were these vulcanos wanting,
 ‘they would be much more annoyed with them
 ‘than now they are; yea, in all probability to that
 ‘degree, as to render the earth, for a vast space
 ‘round them, perfectly uninhabitable. In one word,
 ‘(saith he), so beneficial are these to the territories
 ‘where they are, that there doth not want instances
 ‘of some which have been rescued, and wholly de-
 ‘livered from earthquakes by the breaking forth of
 ‘a new vulcano there; this continually discharging
 ‘that matter, which being till then barricaded up,
 ‘and imprisoned in the bowels of the earth, was the
 ‘occasion of very great and frequent calamities.’
 Thus far that ingenious author.

CHAP. IV.

Of the MOUNTAINS and VALLEYS.

THE last thing I shall take notice of relating to
 the earth, shall be the Hills and Valleys.
 These the eloquent theorist owns to ‘contain some-
 ‘what august and stately in the beholding of them,
 ‘that inspireth the mind with great thoughts and
 ‘passions, that we naturally on such occasions think
 ‘of God and his greatness.’ But then, at the same
 time he saith, ‘The hills are the greatest examples
 ‘of ruin and confusion; that they have neither form,
 ‘nor beauty, nor shape, nor order, any more than
 ‘the clouds in the air; that they consist not of any
 ‘proportion of parts, referable to any design, nor
 ‘have the least footsteps of art or counsel.’ Conse-
 quently one grand part of this lower creation, even
 the whole present face of our terraqueous globe, ac-
 cording to this ingenious author, is a work of mere

chance, a structure in which the Creator did not concern himself.

Part of this charge I have already briefly answered, and my survey now leads me to shew, that the mountains are so far from being a blunder of chance, a work without design, that they are a noble, useful, yea, a necessary part of our globe (a).

And in the first place, as to the business of ornament, beauty, and pleasure, I may appeal to all mens senses, whether the grateful variety of hills and dales, be not more pleasing than the largest continued planes. Let those who make it their business to visit the globe, to divert their sight with the various prospects of the earth; let these, I say, judge whether the far distant parts of the earth would be so well worth visiting, if the earth was every where of an even, level, globous surface, or one large plane of many 1000 miles; and not rather, as now it is, whether it be not far more pleasing to the eye, to view from the tops of the mountains the subjacent vales and streams, and the far distant hills; and a-

(a) ' Though there are some that think mountains to be a deformity to the earth, etc. yet if well considered, they will be found as much to conduce to the beauty and conveniency of the universe, as any of the other parts. Nature (saith Pliny) purposely framed them for many excellent uses; partly to tame the violence of greater rivers, to strengthen certain joints within the veins and bowels of the earth, to break the force of the sea's inundation, and for the safety of the earth's inhabitants, whether beasts or men. That they make much for the protection of beasts, the psalmist testifies, ' The high hills are a refuge for the wild goats, and the rocks for the conies.' The kingly prophet had likewise learnt the safety of those by his own experience, when he also was fain to make a mountain his refuge from the fury of his master Saul, who prosecuted him in the wilderness. True, indeed, such places as these keep their neighbours poor, as being most barren, but yet they preserve them safe, as being most strong; witness our unconquered Wales and Scotland.—Wherefore a good author doth rightly call them nature's bulwarks, cast up at God Almighty's charges, the scorns and curbs of victorious armies; which made the Barbarians, in Curtius, so confident of their own safety,' etc. Bishop Wilkin's World in the Moon, p. 114.

gain from the vales to behold the surrounding mountains. The elegant strains and lofty flights, both of the ancient and modern poets on these occasions, are testimonies of the sense of mankind on this configuration of the earth.

But be the case as it will as to beauty, which is the least valuable consideration, we shall find as to convenience, this configuration of the earth is far the most commodious on several accounts.

1. As it is the most salubrious, of great use to the preservation or restoration of the health of man. Some constitutions are indeed of so happy a strength, and so confirmed an health, as to be indifferent to almost any place or temperature of the air: but then others are so weakly and feeble, as not to be able to bear one, but can live comfortably in another place. With some, the finer and more subtle air of the hills doth best agree, who are languishing and dying in the feculent and grosser air of great towns, or even the warmer and vaporous air of the valleys and waters: but contrarywise others languish on the hills, and grow lusty and strong in the warmer air of the valleys.

So that this opportunity of shifting our abode from the warmer and more vaporous air of the valleys, to the colder and more subtle air of the hills, or from the hills to the vales, is an admirable easement, refreshment, and great benefit to the valitudinarian, feeble part of mankind, affording those an easy and comfortable life, who would otherwise live miserably, languish, and pine away.

2. To this salutary conformation of the earth, we may add another great convenience of the hills, and that is in affording commodious places for habitation: 'Serving (as an eminent author *(b)* wordeth it) 'as skreens to keep off the cold and nipping blasts of

(b) Ray's Wisdom of God, etc. p. 251. Dissolution of the World, p. 35.

‘ the northerly and easterly winds, and reflecting the
 ‘ benign and cherishing sun beams, and so rendering
 ‘ our habitations both more comfortable and more
 ‘ chearly in winter; and promoting the growth of
 ‘ herbs and fruit-trees, and the maturation of the
 ‘ fruits in summer.’

3. Another benefit of the hills is, that they serve for the production of great varieties of herbs and trees (c). And as there was not a better judge of those matters, so I cannot give a better account of this convenience, than in the words of the last cited famous author, the late most eminent and learned Mr Ray (d), (who hath so fully discussed this subject I am upon, that it is scarce possible to tread out of his steps therein). His observation is, ‘ That the mountains do especially abound with different species of vegetables, because of the great diversity of soils that are found there, every vertex or eminence almost affording new kinds. Now these plants, saith he, serve partly for the food and sustenance of such animals as are proper to the mountains, partly for medicinal uses; the chief physic, herbs, and roots, and the best in their kinds growing there: it being remarkable, that the greatest and most luxurious species in most genera of plants are natives of the mountains.’

4. Another convenience which my last named learned friend observes (e) is, ‘ That the mountains serve for the harbour, entertainment, and maintenance of various animals, birds, beasts, and insects, that breed, feed, and frequent there. For,

(c) Theophrastus having reckoned up the trees that delight most in the hills, and others in the valleys, observeth, *παντα δὲ ὅσα κοινὰ τῶν ὄρων ἔ τῶν πεδίων, μίζω μὲν ἔ καλλίω τῇ ὀψι*
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(d) Wisdom of God, p. 352.

(e) Ubi supra.

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 εἰς ἐρυθρὸν ἔ ἐλάδης. -- Τὰ δὲ τὸς εὐσεπιῶς ἔ ἐυελίως. Ib. l. 4. c. 1.

(d) Wisdom of God, p. 352.

(e) Ubi supra.

‘saith he, the highest tops and pikes of the Alps themselves are not destitute of their inhabitants, the Ibex or Stein-buck, the Rupicapra or Chamois, among quadrupeds; the Lagopus among birds. And I myself, saith he, have observed beautiful Papilios, and store of other insects upon the tops of some of the Alpine mountains. Nay, the highest ridges of many of these mountains serve for the maintenance of cattle, for the service of the inhabitants of the valleys.’

5. Another thing he observes is, ‘That those long ridges and chains of lofty and topping mountains, which run through whole continents east and west (*f*), serve to stop the evagation of the vapours to the north and south in hot countries, condensing them like alembic-heads into water, and so (according to his opinion) by a kind of external distillation giving original to springs and rivers; and likewise by amassing, cooling, and constipating of them, turn them into rain, by those means rendering the fervid regions of the torrid zone habitable.

To these might be added some other uses and conveniencies (*g*); as that the hills serve to the genera-

(*f*) Many have taken notice, that some of the greatest eminencies of the world run generally east and west, of which, take the late ingenious and learned Dr Nichol’s account, [Con. with a Theist, Part 2. p. 191.] ‘To go no farther than our own country, all our great ridges of hills in England run east and west; so do the Alps in Italy, and in some measure the Pyrenees; so do the mountains of the moon in Afric, and so do mount Taurus and Caucasus. This, he saith, is a wise contrivance to prevent the vapours, which would all run northwards, and leave no rains in the Mediterranean countries.’

(*g*) That the generation of many of the clouds is owing to the hills, appears from the observations of the ingenious and learned Dr Joh. Jam. Scheuchzer of Zurich, and Mr Joach. Frid. Crellovius cited by him. They observed, at sun-rising, divers clouds detached by the heat of the sun, from some of the tops of the Alps, etc. upon all which their observations, the conclusion is, ‘Mirati summam Creatoris sapientiam, qui et id quod paulo ante nulli nobis usui esse videbatur, maximis rebus destinaverat, adeoque ex illo tempore dubitare coepi, num nubes essent futurae, si istiusmodi montes et petrae non darentur. Hypothesi hac stante, clucesceret permagna utilitas, imo necessitas

tion of minerals and metals (*b*), and that in them principally are the most useful fossils found; or if not found and generated only in them, yet at least all these subterraneous treasures are most easily come at in them: also their use to several nations of the earth, in being boundaries and bulwarks to them. But there is only one use more that I shall insist on; and that is,

6. And lastly, that it is to the hills that the fountains owe their rise, and the rivers their conveyance. As it is not proper, so neither shall I here enter into any dispute about the origin of springs, commonly assigned by curious and learned philosophers. But whether their origin be from condensed vapours, as some think (*i*); or from rains falling, as others; or whether they are derived from the sea by way of attraction, percolation, or distillation; or whether all these causes concur, or only some, still the hills are the grand agent in this prodigious benefit to all the earth: those vast masses and ridges of earth serving as so many huge alembics or cola in this noble work of nature.

But be the *modus*, or the method nature takes in this great work as it will, it is sufficient to my purpose, that the hills are a grand agent in this so noble and necessary a work: and consequently, that those vast masses, and lofty piles, are not, as they are

quam Helveticæ Alpes non nobis tantum accolis sed et vicinis aliis regionibus præstant, dispensando, quas gignunt nubes, ventos, aquas. Scheuch. *Iter. Alpin.* 2. p. 20.

(*b*) Let us take here Ol. Mag. observation of his northern mountains; *Montes excelsi sunt, sed pro majori parte steriles, et aridi; in quibus fere nil aliud pro incolarum commoditate et conservatione gignitur, quam in exhausta pretiosorum metallorum ubertas, qua satis opulenti, fertilesque sunt in omnibus vitæ necessariis, forsitan et superfluis aliunde si libet conquiritis, unanimique robore, ac viribus, ubi vis contra hæc naturæ dona intentata fuerit, defendendis. Acre enim genus hominum est,* etc. Ol. Mag. *Hist. L. 6. Præf.* See also Sir Robert Sibbald's *Prodr. Nat. Hist. Scot.* p. 47.

(*i*) See book I. chap. 3. note (*b*). page 54.

charged, such rude and useless excrescences of our ill-formed globe; but the admirable tools of nature, contrived and ordered by the infinite Creator, to do one of its most useful works, and to dispense this great blessing to all parts of the earth; without which neither animals could live, nor vegetables scarcely grow, nor perhaps minerals, metals, or fossils receive any increase. For, was the surface of the earth even and level, and the middle parts of its islands and continents, not mountainous and high, as now it is, it is most certain there could be no descent for the rivers, no conveyance for the waters: but instead of gliding along those gentle declivities which the higher lands now afford them quite down to the sea, they would stagnate, and perhaps sink, and also drown large tracks of land.

But indeed, without hills, as there could be no rivers, so neither could there be any fountains, or springs about the earth; because if we could suppose a land could be well watered, which I think not possible, without the higher lands, the waters could find no descent, no passage through any commodious outlets, by virtue of their own gravity; and therefore could not break out into those commodious passages and currents, which we every where almost find in, or near the hills, and seldom, or never, in large and spacious planes; and when we do find them in them, it is generally at great and inconvenient depths of the earth; nay, those very subterraneous waters, that are any where met with by digging in these planes, are in all probability owing to the hills, either near or far distant: as among other instances may be made out, from the forcible eruption of the subterraneous waters in digging wells, in the Lower Austria, and the territories of Modena, and Bologna in Italy, mentioned by my forenamed learned friend Mr Ray (*k*). Or if there be any such place

(*k*) * Monsieur Blundel related to the Parisian academy, wha

found throughout the earth, that is devoid of mountains, and yet well watered, as perhaps some small islands may; yet in this very case, that whole mass of land is no other than as one mountain descending, though unperceivedly, gently down from the mid-land parts to the sea, as most other lands do; as is manifest from the descent of their rivers, the principal of which in most countries, have generally their rise in the more lofty mid-land parts.

And now considering what hath been said concerning this last use of the hills, there are two or three acts of the divine providence observable therein. One is, that all countries throughout the whole world, should enjoy this great benefit of mountains, placed here and there, at due and proper distances, to afford the several nations this excellent and most necessary element the waters. For, according to nature's tendency, when the earth and waters were separated, and ordered to their several places, the earth

' device the inhabitants of the Lower Austria, (which is encompassed with the mountains of Stiria), are wont to use to fill their wells with water. They dig in the earth to the depth of 20 and 25 feet, till they come to an argilla [clammy earth] — which they bore through so deep, till the waters break forcibly out; which water, it is probable, comes from the neighbouring mountains in subterraneous channels. And Cassinus observed, that in many places of the territory of Modena and Bologna in Italy, they make themselves wells by the like artifice, etc. By these means the same Seig. Cassini made a fountain at the castle of Urbin, that cast up the water five foot high above the level of the ground.' Ray's Disc. p. 40. ubi plura.

Upon inquiry of some skilful workmen, whose business it is to dig wells, etc. whether they had ever met with the like case, as these in this note; they told me they had met with it in Essex, where, after they had dug to 50 feet deep, the man in the well observed the clayey bottom to swell and begin to send out water, and stamping with his foot to stop the water, he made way for so sudden and forcible a flux of water, that before he could get into his bucket, he was above his waste in water; which soon ascended to 17 feet height, and there stayed: and although they often, with great labour, endeavoured to empty the well, in order to finish their work, yet they could never do it, but were forced to leave it as it was.

must have been of an even surface, or nearly so. The several component parts of the earth must have subsided according to their several specific gravities, and at last have ended in a large, even, spherical surface, every where equidistant from the centre of the globe. But that instead of this form, so incommodious for the conveyance of the waters, it should be jetted out every where into hills and dales, so necessary for that purpose, is a manifest sign of an especial providence of the wise Creator.

So another plain sign of the same especial providence of God, in this matter, is, that generally throughout the whole world, the earth is so disposed, so ordered, so well-laid, I may say, that the midland parts, or parts farthest from the sea, are commonly the highest: which is manifest, I have said, from the descent of the rivers. Now, this is an admirable provision the wise Creator hath made for the commodious passages of the rivers, and for draining the several countries, and carrying off the superfluous waters from the whole earth, which would be as great an annoyance, as now they are a convenience.

Another providential benefit of the hills supplying the earth with water, is, that they are not only instrumental thereby, to the fertility of the valleys, but to their own also (*l*); to the verdure of the vege-

(*l*) As the hills being higher, are naturally disposed to be drier than the valleys; so kind nature hath provided the greater supplies of moisture for them, such at least of them as do not ascend above the clouds and vapours. For, besides the fountains continually watering them, they have more dews and rains commonly than the valleys. They are more frequently covered with fogs; and by retarding, stopping, or compressing the clouds, or by their greater colds condensing them, they have larger quantities of rain fall upon them: as I have found by actual experience, in comparing my observations with those of my late very curious and ingenious correspondent, Richard Townly, Esq; of Lancashire, and some others, to be met with before, book I. chap. 2. note (*a*), p. 45. From which it appears, that above double the quantity of rain falleth in Lancashire, than doth at Westminster: the reason of which is, because Lancashire hath more,

tables without, and to the increment and vigour of the treasures within them.

Thus having vindicated the present form and fabric of the earth, as distributed into mountains and valleys, and thereby shewn in some measure the use thereof, particularly of the mountains, which are chiefly found fault with: I have, I hope, made it in some measure evident, that God was no idle spectator (*m*), nor unconcerned in the ordering of the terraqueous globe, as the former bold charges against it do infer; that he did not suffer so grand a work, as the earth, to go unfinished out of his almighty hand; or leave it to be ordered by chance, by natural gravity, by casual earthquakes, etc. but that the noble strokes, and plain remains of wisdom and power therein, do manifest it to be his work. That particularly the hills and vales, though to a peevish weary traveller, they may seem incommodious and troublesome; yet are a noble work of the great Creator, and wisely appointed by him for the good of our sublunary world.

And so for all the other parts of the terraqueous globe, that are presumed to be found fault with by some, as if carelessly ordered, and made without any design or end; particularly the distribution of the dry land and waters; the laying the several strata, or beds of earth, stone, and other layers before spoken of; the creation of noxious animals, and poisonous substances, the boisterous winds; the vulcanos, and many other things which some are angry with, and will pretend to amend; I have before shewn, that an infinitely wise providence, an almighty hand was concerned even in them; that they all have their

and much higher hills than Essex hath. See book II. chap. 5. note (*f*), p. 77.

(*m*) 'Accusandi sane mea sententia hic sunt sophistae, qui cum nondum invenire, neque exponere opera naturae queant, eam tamen inertia atque inscitia condemnant,' etc. Galen. de Us. Part. I. 10. c. 9.

admirable ends and uses, and are highly instrumental and beneficial to the being, or well-being of this our globe, or to the creatures residing thereon.

So also for human bodies, it hath been an ancient (*n*), as well as modern complaint, that our bodies are not so big as those of other animals; that we cannot run as swift as deer, fly like birds, and that we are outdone by many creatures in the accuracy of the senses, with more to the same purpose. But these objections are well answered by Seneca (*o*), and will receive a fuller solution from what I shall observe of animal bodies hereafter.

But indeed, after all, it is only for want of our knowing these things better, that we do not admire (*p*) them enough; it is our own ignorance, dullness, or prejudice, that makes us charge those noble works of the Almighty, as defects or blunders, as ill-contrived, or ill-made.

(*n*) 'Vide quam iniqui sint divinorum munerum aestimatores, etiam quidem professi sapientiam. Queruntur quod non magnitudine corporis aequemus elephantes, velocitate cervos, levitate aves, impetu tauros; quod solidior sit cutis belluis, decentior damis, densior ursis, mollior fibris: quod sagacitate nos narium canes vincant, quod acie luminum aquilae, spatio aetatis corvi, multo animalia nandi facilitate. Et cum quaedam ne coire quidem in idem natura patiat, ut velocitatem corporis et vires pares animalibus habeamus; ex diversis et dissidentibus bonis hominem non esse compositum, injuriam vocant, et in negligentes nostri deos querimoniam jaciunt, quod non bona valetudo, et vitiis inexpugnabilis data sit, quod non futura scientia. Vix sibi temperant quin eousque impudentiae provehantur, ut naturam oderint, quod infra deos sumus, quod non in aequo illis stetimus.' Seneca, de Benef. l. 2. c. 29.

(*o*) 'Quanto satius est ad contemplationem tot tantorumque beneficiorum reverti, et agere gratias, quod nos in hoc pulcherrimo domicilio voluerunt [dii] secundos sortiri, quod terrenis praefecerunt.' Then having reckoned up many of the privileges and benefits, which the gods, he saith, have conferred upon us, he concludes, 'Ita est: carissimos nos habuerunt dii immortales, habentque. Et qui maximus tribui honos potuit, ab ipsis proximos collocaverunt. Magna accepimus, majorem non cepimus.' Senec. ibid.

(*p*) 'Naturam maxime admiraberis, si omnia ejus opera perscrutaris.' Galen. de Us. Part. l. 11. conclus.

(*q*) Rom.

It is therefore fitter for such finite, weak, ignorant beings as we, to be humble and meek, and conscious of our ignorance, and jealous of our own judgement, when it thus confronteth infinite wisdom. Let us remember how few things we know, how many we err about, and how many we are ignorant of: and those, many of them, the most familiar, obvious things: things that we see and handle at pleasure; yea, our own very bodies, and that very part of us whereby we understand at all, our soul. And should we therefore pretend to censure what God doth! should we pretend to amend his work! or to advise infinite wisdom! or to know the ends and purposes of his infinite will, as if we were of his council! No, let us bear in mind, that these objections are the products, not of reason, but of peevishness. They have been incommoded by storms and tempests; they have been terrified with the burning mountains, and earthquakes; they have been annoyed by the noxious animals, and fatigued by the hills; and therefore are angry, and will pretend to amend these works of the Almighty. But in the words of St Paul (g), we may say, 'Nay but, O man, who art thou that repliest against God? shall the thing formed say to him that formed it, Why hast thou made me thus? Hath not the potter power over the clay, of the same lump to make one vessel to honour, and another to dishonour?' If the almighty Lord of the world had, for his own pleasure, made this our world more inconvenient for man, it would better become us to sit still, and be quiet; to lament our own great infirmities and failings, which deserve a worse place, a more incommodious habitation, than we meet with in this elegant, this well contrived, well formed world; in which we find every thing necessary for the sustentation, use, and pleasure, both of man, and every other creature here below; as well as some whips,

(g) Rom. ix. 20, 21.

some rods to scourge us for our sins (*r*). But yet so admirably well tempered is our state, such an accord, such an harmony is there throughout the creation, that if we will but pursue the ways of piety and virtue, which God hath appointed; if we will form our lives according to the Creator's laws, we may escape the evils of this our frail state, and find sufficient means to make us happy whilst we are in the body. The natural force and tendency of our virtue will prevent many of the harms (*s*), and the watchful providence of our almighty Benefactor will be a guard against others; and then nothing is wanting to make us happy, as long as we are in this world, there being abundantly enough to entertain the minds of the most contemplative; glories enough to please the eye of the most curious and inquisitive; harmonies and comforts of nature's own, as well as man's making, sufficient to delight the ear of the most harmonious and musical; all sorts of pleasant gustos to gratify the taste and appetite, even of the most luxurious; and fragrant odours to please the nicest and tenderest smell: and, in a word, enough to make us love and delight in this world, rather too much, than too

(*r*) 'Neither are they [noxious creatures] of less use to amend our minds, by teaching us care and diligence, and more wit. And so much the more, the worse the things are we see, and should avoid. Weesels, kites, and other mischievous animals, induce us to a watchfulness: thistles and moles to good husbandry; lice oblige us to cleanliness in our bodies; spiders in our houses; and the moth in our clothes. The deformity and filthiness of swine make them the beauty-spot of the animal creation, and the emblems of all vice.—The truth is, things are hurtful to us only by accident; that is, not of necessity, but through our own negligence or mistake. Houses decay, corn is blasted, and the weasel breeds in malt, sooner toward the south. Be it so, it is then our own fault, if we use not the means which nature and art have provided against these inconveniencies.' Grew's *Cosmol.* ch. 2. sect. 49, 50.

(*s*) *Non est gemendus, nec gravi urgendus nece,
Virtute quisquis abstulit fatis iter.*

Senec. *Hercul. Oet.* act. 5. Car. 1839.

*Nunquam stygias fertur ad umbras
Inclyta virtus.*

Id. *ibid.* Car. 1920.

little, considering how nearly we are allied to another world, as well as this.

B O O K IV.

Of ANIMALS in general.

I N the last book, having surveyed the earth itself in particular, I shall next take a view of the inhabitants thereof; or the several kinds of creatures (*a*), that have their habitation, growth, or subsistence thereon.

These creatures are either sensitive, or insensitive creatures.

In speaking of those endowed with sense, I shall consider,

I. Some things common to them all.

II. Things peculiar to their tribes.

I. The things in common, which I intend to take notice of, are these ten :

1. The five senses, and their organs.
2. The great instrument of vitality, respiration.
3. The motion, or loco-motive faculty of animals.
4. The place in which they live and act.
5. The balance of their numbers.
6. Their food.
7. Their cloathing.
8. Their houses, nests, or habitations.
9. Their methods of self-preservation.
10. Their generation, and conservation of their species by that means.

(*a*) Principio coelum, ac terras, camposque liquentes,
Lucentemque globum lunae, Titaniaque astra
Spiritus intus alit, totamque infusa per artus
Mens agitat molem, et magno se corpore miscet.
Inde hominum, pecudumque genus, vitaeque volantum,

CHAP. I.

Of the FIVE SENSES in general.

THE first thing to be considered, in common to all the sensitive creatures, is, their faculty of seeing, hearing, smelling, tasting, and feeling; and the organs ministering to these five senses, together with the exact accommodation of those senses, and their organs, to the state and make of every tribe of animals (*a*). The consideration of which particulars alone, were there no other demonstrations of God, is abundantly sufficient to evince the infinite wisdom, power, and goodness, of the great Creator. For, who can but stand amazed at the glories of these works! at the admirable artifice of them! and at their noble use and performances! For, suppose an animal, as such, had breath and life, and could move itself hither and thither; yet how could it know whither to go, what it was about, where to find its food, how to avoid thousands of dangers (*b*), without sight! How could man, particularly, view the glories of the heavens, survey the beauties of the fields, and enjoy the pleasure of beholding the noble variety of diverting objects, that do, above us in the heavens, and here in this lower world, present themselves to our view every where; how enjoy this, I say, without that admirable sense of sight (*c*)! How

Et quae marmoreo fert monstra sub aequore pontus,
Igneus est illis vigor, et coelestis origo
Seminibus.

Virg. *Aen.* L. 6. Carm. 724

(*a*) 'Ex sensibus ante caetera homini tactus, deinde gustatus, reliquis superatur a multis. Aquilae clarius cernunt: vultures sagacius odorantur, liquidius audiunt talpae obrutae terra, tum denso atque furdo naturae elemento.' Plin. Nat. Hist. l. 10. c. 69.

(*b*) 'Subjacent oculi, pars corporis pretiosissima, et qui lucis usu vitam distinguant a morte.' Plin. Nat. Hist. l. 11. c. 37.

(*c*) 'Foeminae aliquae Megarenses folis oculis discernere valent

could also the animal, without smell and taste, distinguish its food, and discern between wholesome and unwholesome; besides the pleasures of delightful odours, and relishing gustos! how, without that other sense of hearing, could it discern many dangers that are at a distance, understand the mind of others, perceive the harmonious sounds of music, and be delighted with the melodies of the winged choir, and all the rest of harmonies the Creator hath provided for the delight and pleasure of his creatures! And lastly, how could man, or any other creature, distinguish pleasure from pain, health from sickness, and consequently be able to keep their body sound and entire, without the sense of feeling! Here, therefore, we have a glorious œconomy in every animal, that commandeth admiration, and deserveth our contemplation: as will better appear by coming to particulars, and distinctly considering the provision which the Creator hath made for each of these senses.

CHAP. II.

Of the EYE.

FOR our clearer proceeding in the consideration of this noble part (*a*), and understanding its œconomy, I shall consider,

bant inter ova quae ex gallina nigra, et quae ex alba nata sunt,' is what is affirmed, how truly I know not, by Grimald. de Lumin. et Color. Pr. 43. Sect. 60.

(*a*) 'In dissectionibus anatomicis vix aliquid admirabilius, aut artificiosius structura oculi humani, meo quidem judicio, occurrat: ut merito, per-excellentiam, Creatoris appelletur miraculum.' Gul. Fabr. Hildan. Cent. 2. observ. 1.

So likewise that accurate surveyor of the eye, Dr Briggs, whose Ophthalmography I have met with since my penning this part of my survey. His character of this curious piece of God's work is, 'Inter praecipuas corporis animati partes, quae magni cenditoris nostri sapientiam ostendunt, nulla sane reperitur, quae majori pompa elucet quam ipse oculus, aut quae elegantiori forma, concinnatur. Dum enim aliae partes vel minori

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1. The form of the eye.
2. Its situation in the body.
3. Its motions.
4. Its size.
5. Its number.
6. Its parts.
7. The guard and security nature hath provided for this so useful a part.

As this eminent part hath not been pretermitted by authors, that have made it their particular design and business to speak of the works of God; so divers of the aforesaid particulars have been touched upon by them. And therefore I shall take in as little as possible of what they have said, and as near as I can, mention chiefly what they have omitted. And,

1. For the form of the eye; which is for the most part globous, or somewhat of the sphaeroidal form, which is far the more commodious optical form, as being fittest to contain the humours within, and to receive the images of objects from without (*b*). Was it a cube, or of any multangular form, some of its parts would lie too far off (*c*), and some too nigh

‘*satellitio stipantur, vel in tantam vinnstatem haud assurgunt; ocelli peculiarem honorem et decus a supremo numine efflatum referunt, et nunquam non stupendae suae potentiae characteres repraesentant. Nulla sane pars tam divino artificio et ordine,*’ etc. cap. 1. sect. 1.

(*b*) It is a good reason friar Bacon assigns for the sphaericity of the eye: ‘*Nam si esset planae figurae, species rei majoris oculo non posset cadere perpendiculariter super eum—Cum ergo oculus videt magna corpora, ut fere quartam coeli uno aspectu, manifestum est, quod non potest esse planae figurae, nec alicujus nisi sphaericae, quoniam super sphaeram parvam possunt cadere perpendiculares infinitae, quae a magno corpore veniunt, et tendunt in centrum sphaerae: et sic magnum corpus potest ab oculo parvo videri.*’ For the demonstration of which he hath given us a figure. Rog. Bacon. Perspect. Hist. 4. cap. 4.

Dr Briggs saith, ‘*Pars antica, [sive cornea] convexior est posterior: hac enim ratione radii melius in Pupillam detorquentur, et oculi fundus ex altera parte in majorem (propter imagines rerum ibidem delineandos) expanditur.*’ Ibid. sect. 2.

(*c*) Suppose the eye had the retina, or back part, flat for

those lenticular humours, which by their refractions cause vision. But by means of the form before mentioned, the humours of the eye are commodiously laid together, to perform their office of refraction; and the retina, and every other part of that little darkened cell, is neatly adapted regularly to receive the images from without, and to convey them accordingly to the common sensory in the brain.

To this we may add the aptitude of this figure to the motion of the eye; for as it is necessary for the eye to move this way, and that way, in order to adjust itself to the objects it would view; so by this figure it is well prepared for such motions, so that it can with great facility and dexterity direct itself as occasion requires.

And as the figure, so no less commodious is,

2. The situation of the eye; namely, in the head (*d*), the most erect, eminent part of the body, near the most sensible, vital part, the brain. By its eminence in the body, it is prepared to take in the more objects (*e*). And by its situation in the head, besides its proximity to the brain, it is in the most convenient place for defence and security. In the hands, it

the reception of the images, as in Fig. 1. ABA; it is manifest, that if the extremes of the image AA were at a due focal distance, the middle B would be too nigh the crystalline, and consequently appear confused and dim; but all parts of the retina lying at a due focal distance from the crystalline, as at ACA, therefore the image painted thereon is seen distinct and clear. Thus in a dark room, with a lens at a hole in the window, (which Sturmius calls his artificial eye, in his Exercit. Acad. one of which he had made for his pupils, to run any where on wheels): in this room, I say, if the paper that receives the images be too nigh, or too far off the lens, the image will be confused and dim; but in the focus of the glass, distinct, clear, and a pleasant sight.

(*d*) 'Blemmyis traduntur capita abesse, ore et oculis pectore affixis.' Plin. Nat. Hist. l. 5. c. 8. 'Occidentem versus quoddam sine cervice oculos in humeris habentes.' Ib. l. 7 c. 2. From these, and other such like fables, in this last cited chapter of Pliny, no doubt our famous romancer Sir J. Mandeville, had his romantic stories related in his travels.

(*e*) See book v. chap. 2. note (*e*).

might indeed (in man) be rendered more eminent than the head, and be turned about here and there at pleasure: but then it would be exposed to many injuries in that active part, and the hands (*f*) rendered a less active and useful part. And the like may be said to its sight, in any other part of the body, but where it is. But in the head, both of man, and other animals, it is placed in a part that seems to be contrived and made, chiefly for the action of the principal senses.

Another thing observable in the sight of the eye, is the manner of its situation in the head, in the fore-part or side-part thereof, according to the particular occasions of particular animals. In man, and some other creatures, it is placed to look directly forward chiefly; but withal it is so ordered, as to take in near the hemisphere before it. In birds, and some other creatures, the eyes are so seated, as to take in near a whole sphere, that they may the better seek their food, and escape dangers. And in some creatures, they are seated so as to see best behind them (*g*), or on each side, whereby they are enabled to see their enemy that pursues them that way, and so make their escape.

And for the assistance of the eyes, and some of the other senses in their actions, the head is generally made to turn here and there, and move as occasion requires. Which leads me to

3. The third thing to be remarked upon, the motions of the eye itself. And this is generally upwards,

(*f*) Galen deserves to be here consulted, who, in his book *De Usu Partium*, from many considerations of the hand, such as what is here mentioned, as also its structure, site, and use, largely proves and reflects upon the wisdom and providence of the contriver and maker of that part.

(*g*) Thus in hares and conies, their eyes are very protuberant, and placed so much towards the sides of their head, that their two eyes take in nearly a whole sphere: whereas in dogs, that pursue them, the eyes are set more forward in the head, to look that way more than backward.

downwards, backwards, forwards, and every way (*b*), for the better, more easy, and distinct reception of the visual rays.

But where nature any way deviateth from this method, either by denying motion to the eyes, or the head (*i*), it is a very wonderful provision she hath made in the case. Thus for a remedy of this inconvenience, in some creatures their eyes are set out at a distance from the head (*k*), to be circumvolved

(*b*) 'Sed lubricos oculos fecit [Natura] et mobiles, ut et declinarent liquid noceret; et aspectum, quo vellent, facile converterent.' Cic. de Nat. Deor. l. 2. c. 57.

(*i*) 'The eyes of spiders (in some four, in some six, and in some eight) are placed all in the fore-front of their head, (which is round, and without any neck), all diaphanous and transparent, like a locket of diamonds, etc. neither wonder, why providence should be so anomalous in this animal, more than in any other, we know of. For, 1. Since they wanting a neck, cannot move their head, it is requisite that defect should be supplied by the multiplicity of eyes. 2. Since they were to live by catching so nimble a prey as a fly is, they ought to see her every way, and to take her per saltum, as they do, without any motion of the head to discover her: which motion would have scared away so timorous an insect.' Power's Microsc. Observ. p. 11.

'The eyes of the Cameleon resemble a lens, or convex glass, set in a versatile globular socket, which she turneth backward, or any way, without moving her head; and ordinarily the one a contrary, or quite different way from the other.' Dr Goddard in Phil. Trans. No 137.

'But what is more extraordinary in this motion [of the Cameleon's eye] is to see one of the eyes move, whilst the other remains immoveable; and the one to turn forward, at the same time that the other looketh behind; the one to look up to the sky, when the other is fixed on the ground. And these motions to be so extreme, that they do carry the pupilla under the crest which makes the eye-brow, and so far into the canthi, or corners of the eyes, that the sight can discern whatever is done just behind it, and directly before, without turning the head, which is fastened to the shoulders.' Mem. for a Nat. Hist. in Anat. Diss. at Paris. Diss. of Camel p. 22.

(*k*) Snails send out their eyes at a distance, they being contained in their four horns, 'like atramentous spots, sited to the ends of their horns, or rather to the ends of those black filaments or optic nerves, which are sheathed in their horns,' as Dr Power wordeth it, Obs. 31. p. 36. So the ingenious Dr Lister, Exercit. Anat. Cochli. et Limac.

here and there; or, one this, the other that way at pleasure. And in creatures, whose eyes are without motion, as in divers insects; in this case, either they have more than two eyes, or their eyes are nearly two protuberant hemispheres, and each hemisphere often consisting of a prodigious number of other little segments of a sphere (*l*). By which means those creatures are so far from being denied any benefit of that noble and most necessary sense of sight, that they have probably more of it than other creatures, answerable to the rapidity of their flight, and brisk motion; and to their inquests after food, habitation, or repositories of generation, or such other necessity of the animal.

4. Another admirable provision in the eye, is, its size; in some animals large, in some little. It would be endless here to enumerate particulars; as those of quadrupeds, birds, insects, and other terrestrial animals. And as for fishes, they will fall under another part of my survey.

I shall therefore only take notice of its size in one creature, the mole (*m*). As the habitation of that

(*l*) Vid. l. 8. c. 3. note (*a*).

(*m*) Severinus is of Aristotle's, Pliny's, and Alb. Magnus's opinion, that the mole hath no sight; G. Seger. denies any humour to be therein, but thinks they may probably see, because nature made nothing in vain. But Borrichius saith, their eyes have 'appendiculam nerveam in cerebrum euntem, cujus beneficio globuli illi [the little eyes] extra pellem facile poterant exseri, retrahique pro arbitrio——In illis oculorum globulis humor aqueus copiose satis natabat; caeterorum non nisi tenue vestigium.' Blas. Anat. Anim. c. 35.

'Et quoniam natura hoc vitae genus ipsi destinavit, etiam per quam exiguos oculos——dedit eo consilio, ut ii, pretiosissima corporis pars, a terrae pulvere ne affligerentur. Ii insuper pilis tecti, etc. Humores illis oculis insunt, et tunica nigra, uvea, se prodit. Ad hos tramite alio nervus venit.' Schneider in Blas. ibid.

Some time since I made divers accurate dissections of the eyes of moles, with the help of microscopes, having a doubt whether what we take to be eyes, were such or no. And upon a strict scrutiny, I plainly could distinguish the vitreous and crystalline humours, yea, the ligamentum ciliare, and the atramentaceous

uncouth animal is wholly subterraneous, its lodging, its food, its exercises, nay, even all its pastimes and pleasures, are in those subterraneous recesses and passages, which its own industry hath made for itself; so it is an admirable provision made in the size of the eye of that little creature, to answer all its occasions, and, at the same time, to prevent inconveniencies. For, as a little light will suffice an animal living always under ground; so the smallest eye will abundantly supply that occasion. And as a large protuberant eye, like that of other animals, would much annoy this creature in its principal business, of digging for its food and passage; so it is endowed with a very small one, commodiously seated in the head, and well fenced and guarded against the annoyances of the earth.

5. Another thing remarkable in this noble part of animals, is, its number; no less than two (*n*) in any instance that I know of; and in some animals more, as I have already hinted (*o*).

Now, this is an admirable provision; first, for the convenience of taking in the larger angle, or space: and in the next place, the animal is by this provision,

Mucus. The pupil I could manifestly discern to be round, and the cornea copped, or conical: the eye is at a great distance from the brain, the optic nerve very slender and long, reaching from the eye through the intermediate flesh, and so passeth to the brain, along with the pair of nerves reaching to the nose, which are much the largest that are in all the animal. These creatures, I imagine, have the faculty of withdrawing their eyes, if not quite into the head, as snails, yet more or less within the hair, as they have more or less occasion to use or guard their eyes.

Galen saith, moles have eyes, the crystalline and vitreous humours, encompassed with tunics. *De Ul. Part. l. 14. c. 6.* So accurate an anatomist was he for his time.

(*n*) Pliny tells us of a sort of heron with but one eye, but it was only by hearsay. 'Inter aves ardeolarum genera, quos leucos vocant, altero oculo carere tradunt.' *Nat. Hist. l. 11. c. 37.* So the king of the Nigrae that hath but one eye, and that in his forehead, *l. 6. c. 30.* Which fables I take notice of more for the reader's diversion, than any truth in them.

(*o*) *Supra*, note (*i*) page 113.

in some measure, prepared for the misfortune of the loss of one of these noble, and necessary organs of its body.

But then besides all this, there is another thing considerable in this multiply number of the eye; and that is, that the object seen is not multiplied as well as the organ, and appears but one, though seen with two or more eyes (*p*). A manifest sign of the

(*p*) The most celebrated anatomists differ greatly about the reason, why we see not double with two eyes. This Galen and others after him, generally thought to be from a coalition or decussation of the optic nerves, behind the os sphenoides. But whether they decussate, coalesce, or only touch one another, they do not well agree. The Bartholines expressly assert they are united, 'Non per simplicem contractum vel intersectionem in homine, sed totalem substantiae confusionem.' Anat. l. 3. c. 2. And whereas Vesalius, and some others, had found some instances of their being disunited; they say, 'Sed in plerisque ordinariis confunditur interior substantia, ut accurata disquisitioneprehendi.'

But our learned Dr Gibson (Anat. l. iii. c. 10.) saith, they 'are united by the closest conjunction, but not confusion of their fibres.'

But others think the reason is not from any coalescence, contact, or crossing of the optic nerves, but from a sympathy between them. Thus monsieur Cartes is of opinion, that the fibrillae, constituting the medullary part of those nerves, being spread in the retina of each eye, have each of them corresponding parts in the brain; so that when any of those fibrillae are struck by any part of an image, the corresponding parts of the brain are thereby affected, and the soul thereby informed, etc. But see more hereafter under note (*pp*) from Cartes himself.

Some what like this is the notion of our judicious Dr Briggs, who thinks the optic nerves of each eye, consist of homologous fibres, having their rise in the thalamus nervorum opticorum, and thence continued to both the retinae, which are made of them: and farther, that those fibrillae have the same parallelism, tension, etc. in both eyes; and consequently, when an image is painted on the same corresponding, sympathizing parts of each retina, the same effects are produced, the same notice or information is carried to the thalamus, and so imparted to the soul, or judging faculty. That there is such an *ὁμοιοπαθεια* between the retina, etc. he makes very probable. from the ensuing of double vision upon the interruption of the parallelism of the eyes; as when one eye is depressed with the finger, or their symphony interrupted by disease, drunkenness, etc. And lastly, that simple vision is not made in the former way, viz by a decussation of

infinite skill of the Contriver of this so noble a part, and of the exquisite art he employed in the formation thereof. But the design and skill of the infinite Workman will best be set forth by,

6. Surveying the parts and mechanism of this admirable organ, the eye. And here indeed we cannot but stand amazed, when we view its admirable fabric, and consider the prodigious exactness, and the exquisite skill employed in every part ministering to this noble and necessary sense. To pass by its arteries and veins, and such other parts common to the rest of the body, let us cast our eye on its muscles. These we shall find exactly and neatly placed for every motion of the eye. Let us view its tunics, and these we shall find so admirably seated, so well adapted, and of so firm a texture, as to fit every place, to answer every occasion, and to be proof against all common inconveniencies and annoyances. Let us examine its three humours, and these we shall find all of exquisite clearness and transparency, for an easy admission of the rays; well placed for the refracting of them, and formed, particularly the crystalline humour, by the nicest laws of optics, to collect the wandering rays into a point. And, to name no more, let us look into its darkened cell, where those curious humours lie, and into which the glories

conjunction of the optic nerves, he proves, because those nerves are but in few subjects decussated, and in none conjoined otherwise than by a bare contact, which is particularly manifest in fishes; and in some instances it hath been found, that they have been separated without any double vision ensuing thereupon. Vide Brig. Ophthalmog. cap. 11. and 5, and Nov. Vis. Theor. assum.

What the opinion of our justly eminent Sir Isaac Newton is, may be seen in his Optics, Qu. 15. 'Are not the species of objects seen with both eyes, united where the optic nerves meet before they come into the brain, the fibres on the right side of both nerves uniting there? etc. For the optic nerves of such animals as look the same way with both eyes, (as of men, dogs, sheep, oxen, etc.) meet before they come into the brain; but the optic nerves of such animals as do not look the same way with both eyes, (as of fishes, and of the cameleon), do not meet, if I am rightly informed.' Newt. Opt. Qu. 15.

of the heavens and the earth are brought, and exquisitely pictured; and this cell we shall find, without, well prepared by means of its texture, aperture, and colour, to fence off all the useless or noxious rays; and within, as well coated with a dark tegument, that it may not reflect, dissipate, or any way confuse or disturb the beneficial rays (*q*).

But to descend to particulars, although it would be a great demonstration of the glory of God, yet would take up too much time, and hath been, in some measure, done by others that have written of God's works. Passing over therefore what they have observed, I shall, under each principal part, take a transient notice of some things they have omitted, or but slightly spoken of.

And my first remark shall be concerning the muscles of the eye, and their equilibration. Nothing can be more manifestly an act of contrivance and design, than the muscles of the eye, admirably adapted to move it any, and every way; upwards, downwards, to this side or that, or howsoever we please, or there is occasion for, so as to always keep that parallelism of the eye, which is necessary to true vision. For the performance of which service, the form, the position, and the due strength of each muscle, is admirable. And here I might instance the peculiar and artificial structure of the trochlearis, and the augmentation of its power by the trochlea (*r*); the magnitude and

(*q*) 'Nigra est [uvea] ut radios, ab oculi fundo ad anteriorem ejus partem reflexos, obumbret; ne hi, ut ait clar. Cartesius ad oculi fundum retorti ibidem confusam visionem efficerent. Alia forsân ratio hujus nigredinis statuatur, quod radii in visionem superflui, qui ab objectis lateralibus proveniunt hoc ritu absorbeantur. Ita enim e loco obscuro interdiu objecta optime intuemur, quia radii tunc temporis circumfuso lumine non dilutur.' Brigg's Ophthal. cap. 3. sect. 5.

(*r*) 'Admirandum Dei artificium ex diversorum animalium comparatione indices evadit manifestius. Mirantur omnes trochlearem in oculis hominum et quadrupedum, et quidem jure: admirationem omnem superat, quod sine trochlea oculum movens in avibus novum genus trochleae longe artificiosius nescit tandi membranae dederit.' Blas. An. Ani. p. 2. c. 4. ex Stenon

strength of the attollent muscle, somewhat exceeding that of its antagonist; the peculiar muscle, called the seventh, or suspensory muscle (*s*), given to brutes, by reason of the prone posture of their bodies, and frequent occasions to hang down their heads: and I might speak also of the peculiar origin and insertion of the lower oblique muscle (*t*), which is very notable, and many other things relating to these parts; but it would be tedious to descend too much to those admirable particulars. And therefore to close up these remarks, all I shall farther take notice of, shall be only the exquisite equilibration of all these oppo-

[Musculum Trochlearem] ‘per intermediam trochleam tractum, nunquam intueor, quin admirandus mecum, *Ὁ Θεός, exclamem, οὐ μόνον αἱ γεωμετρῆι, ἀλλὰ ὃ αἱ μηχανῆται.*’ I. C. Sturmii Exer. Aca. 9. de Vis. Org. et Rat. c. 3. sect. 4. p. 446.

(*s*) ‘Observare est quod quadrupedes, qui oculos in terram pronos, ac pendulos gerunt, musculum peculiarem habent, quo oculi globus suspenditur—Hoc musculo, bos, equus, ovis, lepus, porcus, etc. praediti sunt: hoc etiam canis instruitur, sed alio modo conformatum habet.’ Wil. de An. Brut. p. 1. c. 15.

Of this opinion also was Bartholine, Anat. l. 3. c. 8. and divers other eminent anatomists.

But Dr Briggs is of opinion, that the adnata, and the other muscles sufficiently answer all those ends ascribed to that muscle by former anatomists, and thinks ‘probabilius itaque esse hunc musculum nervi optici actionem, per vices, confirmare, ne a prono brutorum incessu et copioso affluxu humorum debilitetur.’ Ophthal. c. 2. sect. 2.

The musculus suspensorius being in the porpess, as well as brutes, Dr Tyson thinks the use of it is not to suspend the bulk of the eye, but rather by its equal contraction of the sclerotis to render the ball of the eye more or less spherical, and so fitter for vision. Tyson’s Anat. of the Porpess, p. 39.

(*t*) ‘Musculus obliquus inferior oritur a peculiari quodam foramine in latere orbitae ocularis facto, (contra quam in caeteris, etc.) quo fit ut ex una parte a musculo trochleari, ex altera vero ab hujus musculi commodissima positione, oculus in aequilibrio quodam constitutus, irretorto obtutu versus objecta feratur, nec plus justo accedat versus internum externumve canthum; quae quidem libratio omnino nulla fuisset, absque hujus musculi peculiari originatione (cujus ratio omnes hujusque anatomicos latuit).’ And so this curious anatomist goes on to shew the stupendous artifice of the great Creator in this position of the oblique muscles. Briggs’s Nova Vis. Theor. p. 11. deo libro.

sive and antagonist muscles, affected partly by the equality of the strength; which is the case of the adduct and abduct muscles; partly by their peculiar origin, or the addition of the trochlea, which is the case of the oblique muscles (u); and partly by the natural posture of the body, and the eye, which is the case of the attollent and depriment muscles. By this so curious and exact a libration, not only unseemly contortions, and incommodious vagations of the eye are prevented, but also it is able with great readiness and exactness to apply itself to every object.

As to the tunics of the eye, many things might be taken notice of, the prodigious fineness of the arachnoides, the acute sense of the retina, the delicate transparency of the cornea (x), and the firm and strong texture of that and the sclerotica too; and each of them, in these and every other respect, in the most accurate manner adapted to the place in which it is, and the business it is there to perform. But for a sample, I shall only take notice of that part of the uvea which makes the pupil. It hath been observed by others, particularly by our honourable founder (y), that as we are forced to use various apertures

(u) Besides those particular motions which the eye receives from the oblique muscles, and I may add its libration also in some measure, some anatomists ascribe another no less considerable use to them; namely, to lengthen and shorten the eye, by squeezing and compressing it, to make it correspond to the distances of all objects, according as they are nigh or far off. Thus the ingenious Dr Keil; 'The aqueous humour being the thinnest and most liquid, easily changeth its figure, when either the ligamentum ciliare contracts, or both the oblique muscles squeeze the middle of the ball of the eye, to render it oblong when objects are too near us.' Keil's Anat. chap. 4. sect. 4. See note (z) following page.

(x) 'Quis vero opifex praeter naturam, qua nihil potest esse callidius, tantam solertiam persequi potuisset in sensibus? quod primum oculos membranis tenuissimis vestivit et sepiit; quod primum perlucidas fecit, ut per eas cerni posset: firmas autem, ut continerentur.' Cic. de Nat. Deor. l. 2. c. 57.

(y) Boyle of Final Causes.

to our optic glasses, so nature hath made a far more complete provision in the eyes of animals, to shut out too much, and to admit sufficient light, by the dilatation and contraction of the pupil (z). But it deserveth our especial remark, that these pupils are in divers animals of divers forms, according to their peculiar occasions. In some, particularly in man, it is round; that being the most proper figure for the position of our eyes, and the use we make of them both by day and night. In some other animals it is of a longish form; in some transverse (*aa*), with its aperture large, which is an admirable provision for such creatures to see the better laterally, and thereby avoid inconveniencies, as well as help them to gather their food on the ground, both by day and night. In other animals the fissure of the pupil is erect (*bb*), and

(z) It is easy to be observed, that the pupil openeth in dark places; as also when we look at far distant objects, but contracts by an increase of light, and when the objects are nigh. This motion of the pupil, some say, is effected by the circular and strait fibres of the uvea, and some attribute it to the ligamentum ciliare. Yet I have no great doubt but that they both concur in that action, and that the ligamentum ciliare doth, at the same time the pupil opens or shuts, dilate or compress the crystalline, and bring it nigher unto, or carry it farther off the retina. For the structure of the ligamentum ciliare, and its two sorts of fibres, drawn with the help of a microscope, I shall refer to Mr Cowper's Anat. T. II.

(*aa*) 'In bove, capra, equo, ove, et quibusdam aliis elliptica est [pupilla] ut eo magis in hisce forsan animalibus, quae prono incessu victum in agris quaeritant, radios laterales ad mala et incommoda utrinque devitanda admittat.' Brigg's Oph. c. 7. sect. 6.

'Homini erecto, aliisque, etc. caput erigere, et quaquaversus circumspicere solitis, plurima simul objecta, tum supra, tum infra, tum e latere utroque—visu excipiuntur; quapropter oculis pupilla rotunda esse debet—Attamen bovi, etc. caput fere semper pronum—gerentibus, tantumque coram, et paulo a latere observantur, intuitu opus est: quapropter pupilla—oblonga est,' etc. Willis de Anim. Brut. p. I. c. 15.

(*bb*) Thus cats (their pupils being erect, and the shutting of their eye-lids transverse thereunto) can so close their pupil, as to admit of, as it were, only one single ray of light; and by throwing all open, they can take in all the faintest rays. Which is

also capable of opening wide, and shutting up close. The latter of which serves to exclude the brighter light of the day, and the former to take in the more faint rays of the night, thereby enabling those nocturnal animals (in whom generally this erect form of the pupil is) to catch their prey with the greater facility in the dark (*cc*), to see upwards and downwards, to climb, etc. Thus much for the tunics.

The next thing I shall take notice of, will relate to the humours of the eye, and that only concerning the mechanism of the crystalline humour; not its incomparable transparency; nor its exact lenticular form; nor its curious araneous membrane (*dd*), that

an incomparable provision for these animals, that have occasion to watch and way-lay their prey both by day and night.

(*cc*) There is, besides this large opening of the pupil, in some nocturnal animals, another admirable provision, enabling them to catch their prey in the dark; and that is, a radiation of the eyes: of which Dr Willis thus; ‘Hujus usus est oculi pupillam, quasi jubare insito, illuminare, ut res noctu, et in tenebris possitas conspiciere valeat: quare in seculo plurimum illustris est: at homini, avibus et piscibus deest.’ This illumination he speaks of, is from the tapetum, in the bottom of the eye, or the shining of the retina, round the optic nerve.

Besides which, he saith, the iris hath a faculty also, in some, of darting out rays of light, so as to enable them to see in the dark: of which he tells this story; ‘Novi quendam cerebro calidiori praeditum, qui post uberiores vini generosi potum in nocte atrata sive tenebris profundus, literas distincte legere potuit. Cujus ratio videtur esse, quod spiritus animales velut accensi, adeoque ab hac iride irradianes, jubare insito medium illuminabant.’ Willis, *ibid*.

Such another thing, Pliny tells us, was reported of Tiberius Caesar; ‘Ferunt Tib. Caes. nec alii genitorum mortalium, fuisse naturam, ut expergefactus noctu paulisper, haud alio modo quam luce clara, contueretur omnia.’ Nat. Hist. l. 11. c. 37.

So Dr Briggs; ‘Virum sane callidae indolis novi in comitatu Bedfordensi degentem, qui oculis felineis—donatus est: adeo ut epistolam—mire admodum in loco obscuro (ubi eadem mihi vix apparuit) perlegit. Hujus vero oculi, nisi quod pupilas insigniores obtinere, ab aliorum formatione neutiquam discrepabant.’ Ophthal. c. 5. sect. 12.

(*dd*) The tunica aranea is taken notice of by friar Bacon, who calls it, tela aranea, and saith, ‘in hac continetur—glaciale vel crystallinum.’ Rog. Bacon’s Perspect. Distinct. 2. c. 3. The wrinkling of this, and the cornea, as the skin is of old

constringeth and dilateth it, and so varieth its focus, (if any such variation there be, as some affirm with

persons, he thinks is the cause of the obscurity of the sight in such persons. Bacon, ib. par. 2. cap. 2. But this tunic some deny, and others allow of: Dr A. M. of Trinity-College, Dublin, (in his Relat. of Anat. Obs. on the eyes of animals, in a letter to Mr Boyle, An. 1682. annexed to his Anat. Account of the Elephant burnt in Dublin, p. 57.) affirms the tunica aranea, and saith, 'I have often seen it before it was exposed to the air one minute, notwithstanding what Dr Briggs saith to the contrary,' etc. But Dr Briggs' opinion is, 'Humor crystallinus, nisi aeri diutius expositus, vel leniter coctus, instar lactis, cuticulam non acquirit: quae vero improprie, tunica aranea dicitur, cum sit tantum adventitia, ut in oculo bovis recens erecto appareat.' Briggs' Ophthalm. c. 3.

The crystalline humour being of a double substance, outwardly like a jelly, towards the centre as consistent as hard suet, upon occasion whereof its figure may be varied; which variation may be made by the ligamentum ciliare; Dr Grew doth, upon these accounts, not doubt to ascribe to the ligamentum ciliare, a power of making the crystalline more convex, as well as of moving it to or from the retina. See Grew's Cosmolog. Sacr. l. 1. c. 4. Now, it is certain, by the laws of optics, that somewhat of this is absolutely necessary to distinct vision, inasmuch as the rays proceeding from nigh objects do more diverge, and those from distant objects less: which requires either that the crystalline humour should be made more convex, or more flat; or else an elongation, or shortening of the eye, or of the distance between the crystalline humour and the retina.

But although Dr Briggs, so good a judge, denies the tunica crystallina, contrary to the opinion of most former anatomists; yet there is great reason to conclude he was in a mistake, in my opinion, from the observations of the French anatomists, of the crystalline of the eye of the gemp or chamois, who say, 'the membrana arachnoides was very thick, and hard, so that it was easily separated from the crystallinus.' P. 145.

The same anatomists also favour the surmise of Dr Grew, 'This [contraction of the fibres of the ligamentum ciliare on one side, and dilatation on the other] would make us think that these fibres of the ligamentum ciliare, are capable of contraction, and voluntary dilatation, like that of the fibres of the muscles; and that this action may augment, or diminish the convexity of the crystallinus, according as the need which the distance of the objects may make it to have on the eye, to see more clearly and distinctly.' Anat. Descri. of a bear, p. 49.

Since my penning the foregoing notes, having as critically as I could, dissected many eyes of birds, beasts, and fishes, I manifestly found the membrana arachnoides, and will undertake to shew it any one, with great ease and certainty. It is indeed so

great probability); nor lastly, its admirable approach to or from the retina, by the help of the ciliar ligament (*ee*), according as objects are far off or near; because these things are what are usually taken notice

transparent, as not to be seen distinct from the crystalline. But if the cornea and uvea be taken off before, or the vitreous humour behind it, and the outside of the crystalline be gently cut, the arachnoides may be seen to open, and the crystalline will easily leap out, and part from the ligamentum ciliare; which otherwise it would not do: for it is by the arachnoides braced to the ligamentum ciliare. This membrane or tunic, in the ox, is so substantial and strong, though thin, that it yields to, or sinks under the sharpest lancet, and requires (for so thin and weak a membrane in appearance) a strong pressure to pierce it.

(*ee*) As birds and fishes are in divers things conformable, so in some sort they are in their eye, to enable it to correspond to all the convergences, and divergences of the rays, which the variation of each of the mediums may produce. For this service the tunica choroides [in fishes] hath a musculous substance at the bottom of it, lying round the optic nerve, at a small distance from it; by which means I imagine they are able to contract, and dilate the choroides, thereby to lengthen and shorten the eye: for the helping in which service, I imagine it is that the choroides and sclerotica, are in a great measure parted, that the choroides may have the greater liberty of acting upon the humours within.

But in birds, I have myself found, that although the choroides be parted from the sclerotica, yet the choroides hath no muscle, but instead thereof, a curious pectinated work, seated on the optic nerve, represented in Fig. 2. In which, c. a. e. b. d. represents the choroides and sclerotica; a. b. the part of the optic nerve that is within the eye; v. v. v. the vitreous humour; a. f. g. b. the pecten; h. i. the crystalline. For the reception of this pecten, the optic nerve comes farther within the eye, than in other creatures. The structure of this pecten is very like that of the ligamentum ciliare: and in the eye of a magpy, and some others, I could perceive it to be musculous towards the bottom. This pecten is so firmly fixed unto, or embodied in the vitreous humour, that the vitreous humour hangs firmly to it, and is not so easily parted from it. By which means all the motions of the pecten are easily communicated to the vitreous humour, and indeed to all contained in the choroides. And forasmuch as the crystalline is connected to the vitreous humour, therefore also the alterations in the vitreous humour affect also the crystalline; and the crystalline hereby brought nearer unto, or farther from the retina, as occasion is.

Besides all which observables in the choroides, and inner eye, I have also found this farther remarkable in the sclerotica, and

of: but that which I shall observe is, the prodigious art and finery of its constituent parts, it being, according to some late nice microscopical observations (*f*), composed of divers thin scales, and these made up of one single minutest thread or fibre, wound

outer-part of the eye of birds, viz that the fore-part of the sclerotic is horny and hard, the middle part thin and flexible, and braces intervene between the fore and hind-part, running between the choroides and sclerotic; by which means the cornea, and back-part of the eye, are brought to the same conformity, that the rest of the eye hath.

The great end and design of this singular and curious apparatus in the eyes, both of birds and fishes, I take to be, 1. To enable those creatures to see at all distances, far off, or high; which, especially in the waters, requireth a different conformation of the eye. In birds also, this is of great use, to enable them to see their food at their bill's end, or to reach the utmost distances their high flights enable them to view; as to see over great tracks of sea or land, whither they have occasion to fly; or to see their food or prey, even small fishes in the waters, and birds, worms, etc. on the earth, when they sit upon trees, high rocks, or are hovering high in the air. 2. To enable those animals to adapt their eye to all the various refractions of their medium. Even the air itself varies the refractions, according as it is rarer or denser, more or less compressed; as is manifest from the learned and ingenious Mr Lowthorp's experiment in Phil. Trans. No. 257. and some other experiments since of the before-commended Mr Hawksbee, both in natural, rarified, and compressed air; in each of which, the refractions constantly varied in exact proportion to the rarity or density of the air. Vide Hawksbee's Exp. p. 175, etc.

Besides this conformity in general, between the eyes of birds and fishes, Du Hamel tells us of a singular conformity in the coramant's eye, and that is, that the crystalline is globous, as in fishes, to enable it to see and pursue its prey under water: which J. Faber, in Mr Willoughby, saith, they do 'with wonderful swiftness, and for a long time.' Will. Ornithol. p. 329.

(*f*) The crystalline humour, when dried, doth manifestly enough appear to be made up of many very thin spherical laminae, or scales lying upon one another. Mr Lewenhoeck reckons there may be two thousand of them in one crystalline, from the outermost to the centre. Every one of these scales, he saith, he hath discovered to be made up of one single fibre, or finest thread wound, in a most stupendous manner, this way, and that way, so as to run several courses, and meet in as many centres, and yet not to interfere, or cross one another, in any one place. In oxen, sheep, hogs, dogs, and cats, the thread spreads into three several courses, and makes as many centres; in whales

round and round, so as not to cross one another in any one place, and yet to meet, some in two, and some in more different centres; a web not to be woven, an optic lens, not to be wrought by any art less than infinite wisdom.

Lastly, To conclude the parts of this admirable organ, I shall only make one remark more, and that about its nerves. And here among others, the admirable make of the optic nerves might deserve to be taken notice of in the first place, their medullary part (*gg*) terminating in the brain itself, the teguments propagated from the meninges, and terminating in the coats of the eye, and their commodious insertions into the ball of the eye, in some directly opposite to the pupil of the eye, in others obliquely towards one side (*hh*). But most of these things have been treated of, and the convenience hereof set forth, by others that have written of God's works. I shall therefore take notice only of one wise provision the Creator hath made about the motion of the eye, by uniting into one, the

five; but in hares and rabbits only two. In the whole surface of an ox's crystalline, he reckons there are more than twelve thousand fibres juxtaposed. For the clear and right understanding of the manner of which admirable piece of mechanism, I shall refer to his cuts and descriptions in *Phil. Transf. No. 165*, and 193. The truth hereof I have heard some ingenious men question; but it is what I myself have seen, and can shew to any body with the help of a good microscope.

(*gg*) S. Malpighi observed the middle of the optic nerve of the sword fish, to be nothing else but a large membrane, folded according to its length in many doubles, almost like a fan, and invested by the dura mater; whereas in land animals it is a bundle of fibres. Vide *Phil. Transf. No. 27*.

(*hh*) 'Certissimum est, quod in omnibus oculis humanis, quod saltem mihi, dissecare contingit, nervus opticus pupillae e diametro opponitur,' etc. *Brigg's Ophthal. cap. 3. sect. 15.* It is also in *Willis de Anim. Brut. p. 1. c. 15.*

'Nervi optici in nobis, item in cane, felle, et in caeteris forsan animalibus calidis, ad fundum oculi delati pupillae regionem prospicunt, dum interim in aliis quadrupedibus, uti etiam in piscibus et volucris, oblique semper tunicae sclerotidi inserti ruuntur.' *Willis ib. cap. 7. sect. 11.*

third pair of nerves, called the motory nerve (ii), each of which sending its branches into each muscle of each eye, would cause a distortion in the eyes; but being united into one, near their insertion into the brain, do thereby cause both eyes to have the same motion; so that when one eye is moved this way and that way, to this and that object, the other eye is turned the same way also.

Thus from this transient and slight view, I may call it, of the parts of the eye, it appears what an admirable Artist was the contriver thereof. And now in,

The seventh and last place, let us consider what provision this admirable Artist hath made for the guard and security of this so well formed organ (kk). And

(ii) 'This pair is united at its rise; whence is commonly drawn a reason why one eye being moved towards an object, the other is directed also to the same.' Gibson's Anat. book iii. chap. 11. So Bortholine Anat. Libellus iii. cap. 2.

(kk) Among all the other security the eye hath, we may reckon the reparation of the aqueous humour; by which means the eye when wounded, and that in all appearance very dangerously too, doth often recover its sight: of which Bern. Verzsacha gives divers examples ancient and modern. One is from Galen, of a boy so wounded, that the cornea fell, and became flaccid, but yet recovered his sight. Other such like instances he gives from Realdus Columbus, Rhodius, and Tulpinus; and one that he cured himself, in these words; 'Ego in nobilissimi viri filiola similem casum observavi; haec dum levibus de causis cum fratre altercare, ille iracundia percitus cultellum scriptorium apprehendit, et sororis oculo vulnus infligit, inde humor aqueus effluxit. Vocatus praesentem chirurgum jussi sequens collyrium anodynum et exsiccans tepide saepius admove. R. aq. Plantag. 3 iv. Rosar. Sanicul. Euphras. ana Trochisc. alb. Rhaf. cum Opio ʒ ij. Tutiae pp. ʒ j. Croci orient. ʒ β. M. Hoc collyrium inflammationem compescuit, vulnus succavit et sanavit. Hinc post aliquot menses humor aqueus succrevit. Nam visus, sed debilior, cum summo parentum gaudio rediit.' B. Verzsachae Observ. Medicae. Obs. 14.

Another cure of this kind, was experimented by Dr Daniel Major, upon a goose, Ann. 1670. the aqueous humour of both whose eyes they let out, so that the eyes fell, and the goose became quite blind; but without the use of any medicine, in about two days time nature repaired the watery humour again, the

here we shall find the guard equivalent to the use and excellency of the part. The whole organ fortified and fenced with strong, compact bones, lodged in a strong, well made socket, and the eye itself guarded with a nice made cover (//). Its humours, and its

eyes returned to their former turgency, and the goose was in a week after produced seeing, before twenty-eight or thirty spectators. *Ephem. Germ. T. 1. Add. ad Obs. 217.*

From the same cause, I doubt not, it was that the eye of a gentleman's daughter, and those of a cock, when wounded, so that the cornea sunk, were restored by a Lithuanian chymist, that passed for a conjurer, by the use of a liquor found in May, in the vesiculæ of elm. Of which see Mr Ray's *Catal. Cantab.* in *Ulmus*, from *Henr. ab Heers*.

(//) 'Palpebrae, quae sunt tegumenta oculorum, molliissimae tactu, ne laederent aciem, aptissimae factae, et ad claudendas pupillas, ne quid incideret, et ad aperiendas; idque providit, ut identidem fieri posset cum maxima celeritate. Munitaeque sunt palpebrae tanquam vallo pilorum: quibus et apertis oculis, si quid incideret, repelleretur, et somno conniventibus, cum oculis ad cernendum non egeremus, ut qui, tanquam involuti, quiescerent. Latent praeterea utiliter, et excelsis undique partibus sepiuntur. Primum enim superiora supercilii obducta sudorem a capite, et fronte defluentem repellunt. Genae deinde ab inferiore putantur subjectae, leviterque eminentes.' *Cic. de Nat. Deor. l. 2. c. 57.*

Tully, in the person of a Stoic, having so well accounted for the use of the eye-lids, I shall, for a further manifestation of the Creator's contrivance and structure of them, take notice of two or three things: 1. They consist of a thin and flexible, but strong skin, by which means they the better wipe, clean, and guard the cornea. 2. Their edges are fortified with a soft cartilage, by which means they are not only enabled the better to do their office, but also to close and shut the better. 3. Out of these cartilages grows a pallisade of stiff hairs, of great use to warn the eye of the invasion of dangers, to keep off motes, and to shut out too excessive light, etc. and at the same time to admit of, through their intervals, a sufficient passage for objects to approach the eye. And it is remarkable, that these hairs grow but to a certain, commodious length, and need no cutting, as many other hairs of the body do: also, that their points stand out of the way, and in the upper-lid bend upwards, as they do downwards in the lower lid, whereby they are well adapted to their use. From which last observables, we may learn how critical and nice the great Author of nature hath been, in even the least and most trivial conveniencies belonging to animal bodies; for which reason I have added it to Tully's remarks. And more might have been added too, as particularly concerning the curious structure

inward tunics, are indeed tender, proportionate to their tender, curious uses; but the coats without are context and callous, firm and strong. And in some animals, particularly birds (*mm*), some part of those

and lodgment of the right muscle, which opens the eye-lids; and the orbicularis, or circular one, that shuts them; the nice apparatus of glands that keep the eye moist, and serve for tears; together with the reason why man alone, who is a social animal, doth exhibit his social affections by such outward tokens as tears; the nerves also, and other organs acting in this ministry. I might also speak of the passages for discharging the superfluous moisture of the eyes through the nostrils, and much more of the like kind. But it would take up too much room in these notes; and therefore it shall suffice to give only such hints as may create a suspicion of a noble oeconomy and contrivance in this, I had almost said, least considerable part of the eye. But for particulars I shall refer to the anatomists; and for some of these things, particularly to Dr Willis's *Cereb. Anat.* and *de Anim. Brut.* and Mr Cowper's elegant cuts in the 11th tab. of his *Anatomy*.

To the eye-lids we may add another guard afforded the eyes of most quadrupeds, birds, and fishes, by the nictitating membrane, which Dr Willis gives this account of; 'Plurimis [animalibus] quibus musculus suspensorius adest (which limitation he needed not to have added) etiam alter membranofus conceditur, qui juxta interiorem oculi canthum situs, quando elevatur, oculi globum fere totum obtegit. Hujus usus esse videtur, ut cum bestiae inter gramina, etc. capita sua propter victum capeffendum demergunt, hic musculus oculi pupillam, ne a stipularum incurfu feriatur, occultit munitque.' *De Anim. Brut.* p. 1. c. 15. This membrane man hath not, he having little occasion to thrust his head into such places of annoyance, as beasts, and other animals; or if he hath, he can defend his eyes with his hands. But birds, (who frequent trees and bushes), and quadrupeds, (hedges and long grass), and who have no part ready, like the hand, to wipe off annoyances; these, I say, have this incomparable provision made for the safety of their eyes. And for fishes, as they are destitute of eye-lids, because in the waters there is no occasion for a defensive against dust and motes, offensive to the eyes of land-animals, nor to moisten and wipe the eyes, as the eye-lids do, so the nictitating membrane is an abundant provision for all their occasions, without the addition of the eye-lids.

And now, if we reflect, are these the works of any thing but wise and indulgent Agent?

(*mm*) Although the hardness and firmness of the adnata, or sclerotic in birds, is a good guard to their eyes, yet I do not think it is made thus, so much for a defence, as to minister to the lengthening and shortening the eye, mentioned before in note (*dd*).

tunics have the nature and hardness of bone or horn.

But for creatures, whose eyes, like the rest of their body, are tender, and without the guard of bones, their nature hath provided for this necessary and tender sense, a wonderful kind of guard, by endowing the creature with a faculty of withdrawing its eyes into its head (*nn*), and lodging them in the same safety with the body.

Thus have I surveyed this first sense of animals, I may say in a cursory, not accurate, strict manner considering the prodigious workmanship thereof; but so, as abundantly to demonstrate it to be the contrivance, the work of no less a being than the infinite wise, potent, and indulgent Creator (*oo*). For none less could compose so admirable an organ, so adapt all its parts, so adjust it to all occasions, so nicely provide for every use, and for every emergency: in a word, none less than God could, I say, thus contrive, order, and provide an organ, as magnificent and curious as the sense is useful; a sense without which, as all the animal world would be in perpetual darkness, so it would labour under perpetual inconveniencies, be exposed to perpetual harms, and suffer perpetual wants and distresses. But now to this admirable sense, the great God, who hath placed us in this world, hath as well provided for our comfortable residence in it; enabled us to see and choose wholesome, yea, delicate food; to provide ourselves useful, yea, gaudy cloathing, and commodious places of habitation and retreat. We can now dispatch our affairs with alacrity and pleasure.

(*nn*) 'Cochleis oculorum vicem cornicula bina praetentur' Plin. Nat. Hist. l. 11. c. 37. See more in the eyes of snails before in note (*k*); and in note (*m*) I said that I suspected moles also might thrust out, or withdraw their eyes more or less within the hair or skin.

(*oo*) The diligent Sturmius was fully persuaded there could be any speculative atheism in any one that should well survey

go here and there as our occasion calls us. We can, if need be, ransack the whole globe, penetrate into the bowels of the earth, descend to the bottom of the deep, travel to the farthest regions of this world, to acquire wealth, to increase our knowledge, or even only to please our eye and fancy. We can now look about us, discern and shun the precipices and dangers which every where inclose us, and would destroy us. And those glorious objects which fill the heavens and the earth, those admirable works of God which every where surround us, and which would be nothing to us, without being seen, do, by means of this noble sense, present their glories to us (*pp*),

the eye. 'Nobis, saith he, fuit persuasissimum, atheismum, quem vocant speculativum, h. e. obfirmatam de Deitate in universo nulla persuasionem, habere locum aut inveniri non posse in eo homine, qui vel unius corporis organici, et speciatim oculi fabricam attento animo aspexerit.' Sturm. Exerc. Acad. 9: de H. Organ. et Rat. in Epilogo.

(*pp*) The glorious landksips, and other objects that present themselves to the eye, are manifestly painted on the retina, and that not erect, but inverted as the laws of optics require; and is manifest to the eye from monsieur Cartes's experiment, of laying over the vitreous humour on the back part of the eye, and clapping over it a bit of white paper, or the skin of an egg; and then placing the fore-part of the eye to the hole of the window of a darkened room. By which means we have a pretty landskip of the objects abroad invertedly painted on the paper, on the back of the eye. But now the question is, how in this case the eye comes to see the objects erect? Monsieur Cartes's answer is, 'Notitia illius ex nulla imagine pendet, nec ex ulla actione ab objectis veniente, sed ex solo situ exiguarum partium cerebri, e quibus nervi expullulant.'—E. G. Cogitandum in oculo—situs capillamenti nervi optici—respondere et alium quendam partis cerebri—qui facit ut anima singula loca cognoscat, quae jacet in recta, aut quasi recta linea; ut ita mirari non debeamus corpora in naturali situ videri, quamvis imago in oculo delineata contrarium habeat.' Dioptr. c. 6. But our most ingenious Mr Polynex answereth thus; 'The eye is only the organ or instrument, it is the soul that sees by means of the eye. To inquire then how the soul perceives the object erect, by an inverted image, is to inquire into the soul's faculties—but erect and inverted are only terms of relation to up and down; or farther from, or nigher to the centre of the earth, in parts of the same thing.—But the eye, or visive faculty takes no notice of the internal posture of its own parts, but useth them

and fill us with admiration and pleasure. But I need not expatiate in the usefulness and praises of this sense, which we receive the benefit of every moment, and the want, or any defect of which, we lament among our greatest misfortunes.

Leaving then this sense, I shall proceed to the other four, but more briefly treat of them, by reason we have so ample a sample of the divine art in the last, and may presume that the same is exerted in all as well as one. For a demonstration of which, let us, in the next place, carry our scrutiny to the sense of hearing.

CH A P. III.

Of the Sense of HEARING.

CONCERNING the sense of Hearing, I shall take notice of two things, the organ, the ear; and its object, sound.

I. For the organ, the ear; I shall pass by its convenient number of being double, which, as in the last sense, serves for the commodious hearing every way round us; as also a wise provision for the utter loss or injury (*a*) of one of the ears. But I shall

* as an instrument only, contrived by nature for the exercise of such a faculty. — Let us imagine, that the eye (on its lower part) receives an impulse [by a ray from the upper part of the object]; must not the visive faculty be necessarily directed hereby to consider this stroke, as coming from the top rather than the bottom [of the object], and consequently be directed to conclude it the representation of the top? Hereof we may be satisfied, by supposing a man standing on his head. For he though the upper parts of the objects are painted on the upper parts of the eye, yet the objects are judged to be erect. What is said of erect, and reverse, may be understood of sinister and dexter.* Molyn. Dioptr. Nov. part 1. prop. 28.

(*a*) I presume it will not be ungrateful to take notice here of the admirable, as well as useful sagacity of some deaf persons that have learned to supply their want of hearing by understanding what is said by the motion of the lips. My very ingenious

little insist upon its situation, and its admirable fabric and parts.

1. It is situated in the most convenient part of the body, like as I said the eye is, in a part near the common sensory in the brain, to give the more speedy information; in a part where it can be best guarded, and where it is most free from annoyances and harms itself, and where it gives the least annoyance and hindrance to the exercises of any other part; in a part appropriated to the peculiar use of the principal senses, in the most lofty, eminent part of the body, where it can perceive the most objects, and receive the greatest information: and lastly, in a

friend, Mr Waller, R. S. Secr. gives this account: 'There live now, and have from their birth, in our town, a man and his sister, each about fifty years old, neither of which have the least sense of hearing,—yet both of these know, by the motion of the lips only, whatever is said to them, and will answer pertinently to the question proposed to them.—The mother told me they could hear very well, and speak when they were children, but both lost that sense afterwards, which makes them retain their speech; though that, to persons not used to them, is a little uncouth and odd, but intelligible enough.' Phil. Transf. No. 312.

Such another instance is that of Mr Goddy, minister of St Gervais in Geneva, his daughter. 'She is now about sixteen years old. Her nurse had an extraordinary thickness of hearing; at a year old, the child spake all those little words that children begin to speak at that age.—At two years old, they perceived she had lost her hearing, and was so deaf, that ever since, though she hears great noises, yet she hears nothing that one can speak to her.—But by observing the motions of the mouth and lips of others, she hath acquired so many words, that out of these she hath formed a sort of jargon, in which she can hold conversation whole days with those that can speak her own language. I could understand some of her words, but could not comprehend a period, for it seemed to be but a confused noise. She knows nothing that is said to her, unless she seeth the motion of their mouths that speak to her; so that in the night, when it is necessary to speak to her, they must light a candle. Only one thing appeared the strangest part of the whole narration: she hath a sister, with whom she hath practised her language more than with any other: and in the night by laying her hand on her sister's mouth, she can perceive by that what she saith, and so can discourse with her in the night.' Bishop Burnet's Let. 4. p. 248.

part in the neighbourhood of its sister sense the eye, with whom it hath peculiar and admirable communication by its nerves, as I intend to shew in its proper place. In respect then of its situation and place in the body, this sense is well designed and contrived, and may so far be accounted the work of some admirable Artift. But,

2. If we survey its fabric and parts, it will appear to be an admirable piece of the divine wisdom, art, and power. For the manifestation of which, let us distinctly survey the outward and the inward part of its curious organ.

1. For the outward ear: if we observe its structure in all kinds of animals, it must needs be acknowledged to be admirably artificial, it being so nicely prepared and adjusted to the peculiar occasions of each respective animal. In man (*b*), it is of a form proper for the erect posture of his body. In birds, of a form proper for flight; not protuberant, because that would obstruct their progress, but close

(*b*) I cannot but admire that our most eminent modern anatomists should not agree, whether there be any muscles in the outward ear of man or not. Dr Keil saith there are two; Dr Drake the same number; and Dr Gibson makes them to be four. So also doth monfieur Dionis, and so did the ancient anatomists: but Dr Schelhammer expressly denies there are any, and saith, '*Seduxit it autem reliquos brutorum anatome, in quorum plerisque tales musculi plures inveniuntur; putarunt autem fortassis ignominiosum homini, si non et his instructus esset, et minus inde perfectum animal fore.*' Schel. de Auditu, p. 1. c. 1. sect. 7. But Valsalva, who wrote very lately, and is very accurate in his survey of the ear, saith, '*Musculi auriculæ posteriores quandoque quatuor, quandoque duo; sed ut plurimum tres adnotantur; et quando solum duo se manifestant, tunc unus ex illis duplicato tendine versus concham deferri solet. Horum musculorum in numero varietatem non solum in diversis; verum etiam in eodem subjecto quandoque vidi—Ex quibus differentiis subortae sunt auctorum discrepantiae in horum musculorum numero, et positu:—quod non evenisset, si pluries in diversis corporibus iidem musculi quaesiti essent.*' Ant. Mar. Valsalva de Aur. Human. c. 1. sect. 6. But Dr Drake thinks some of Valsalva's muscles the product of fancy. Mr Cowper makes them to be three, one attollent, and two retrahent muscles. See Anat. Tab. 12.

and covered, to afford the easier passage through the air. In quadrupeds, its form is agreeable to the posture, and slower motion of their bodies; and in these too, various, according to their various occasions. In some large, erect, and open, to hear the least approaches of danger (c); in others covered, to keep out noxious bodies. In the subterraneous quadrupeds, who are forced to mine and dig for their food and habitation, as a protuberant ear, like that of other quadrupeds, would obstruct their labours, and be apt to be torn and injured; so they have the contrary (d), their ears short, lodged deep and backward in their

(c) ' Inter caetera [animalia aurita] maxime admirabilis est auris leporinae fabrica, quod cum timidissimum animal sit, et prorsus inerme, natura id tum auditu acutissimo, tanquam hostium exploratore ad praesentienda pericula, tum pedibus ceu armis ad currendum aptis munisse videtur.' A. Kircher's *Phonurg.* l. 1. sect. 7. Technas. 2.

(d) Moles have no protuberant ear, but only a round hole between the neck and shoulder; which situation of it, together with the thick, short fur that covers it, is a sufficient defensive against external annoyances. The meatus auditorius is long, round, and cartilaginous, reaching to the under part of the skull. Round the inside runs a little ridge, resembling two threads of a skrew; at the bottom whereof is a pretty inlet leading to the drum, made, on one side, with the aforesaid cochleous ridge, and on the other with a small cartilage. I observed there was cerumen in the meatus.

As to the inner ear, it is somewhat singular, and different from that of the other quadrupeds, and much more from birds; although I have met with some authors that make it agreeable with that of birds. There are three small bones only, all hollow, by which the drum, to use the old appellation, or the membrana tympani, as others call it, acteth upon the auditory nerve. The first is the malleus, which hath two processes nearly of equal length; the longer of which is braced to the membrana tympani, the shorter to the side of the drum, or os petrosum; the back part of it resembles the head and stalk of a small mushroom, such as are pickled. On the back of the malleus lies the next small bone, which may be called the incus, long and without any process, having somewhat the form of the short scoop wherewith watermen throw the water out of their wherries. To the end of this, the third and last small bone is tacked by a very tender brace. This little bone bears the office of the stapes, but is only forked without any base. One of these forks is, at one fenestra, or foramen, the other at another; in which fenestrae

head, and passing to the under part thereof, and all sufficiently fenced and guarded. And as for insects, reptiles, and the inhabitants of the waters, if they enjoy this sense, as there is great reason to think they do, it may probably be lodged commodiously under the same security and guard, as the smelling, or some other sense is.

And moreover, as the form of this organ is various in various animals, so in each of them its structure is very curious and observable, being in all admirably contrived to collect the wandering, circumambient impressions and undulations of sound, and convey them to the sensory within. If I should run over the several genera of animals, we might find a notable prospect of the handy-work of God (e), even in

I apprehend the forks are tacked to the auditory nerve. These fenestrae (equivalent to the fenestra ovalis, and rotunda in others) are the inlets into the cochlea and canales semicirculares, in which the auditory nerve lieth. The semicircular canals lie at a distance from the drum, and are not lodged, as in other animals, in a strong, thick body of bone, but are thrust out within the skull, making an antrum, with an handsome arch leading into it, into which a part of the brain enters.

One leg of the malleus being fastened to the membrana tympani, and the incus to the back of the malleus, and the top of that to the top of the stapes, and the forks or branches of the stapes to the auditory nerve, I observed that whenever I moved the membrane, all the little bones were at the same time moved, and consequently the auditory nerve thereby affected also.

I hope the reader will excuse me for being so particular in this organ only of the mole, a despised creature, but as notable an example of God's work, as its life is different from that of other quadrupeds; for which reason it partly is that I have enlarged on this part differing from that of others, and which no body that I know of, hath taken much notice of, and which is not discoverable without great patience and application; and partly because by comparing those observations with book vii. chap. 2. note (e), we may judge how the sense of hearing is performed.

(e) Among many varieties, both in the inner and outer ear, those which appear in the passage into the rock-bone, are remarkable. For in an owl, that perches on a tree or beam, and hearkens after the prey beneath her, it is produced farther out above than it is below, for the better reception of the least sound. But in a fox, that scouteth underneath the prey at roost, it is

for the same reason produced farther out below. In a pole-cat,

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this so inconsiderable a part of animals. But I shall only carry my survey to that of man. And here the first thing that offereth itself to our view, is the helix, with its tortuous cavities, made to stop, and collect the sonorous undulations, to give them a gentle circulation and refraction, and so convey them to the concha, or larger and more capacious round cell at the entrance of the ear. And to bridle the evagation of the sound, when arrived so far, but without not to make a confusion thereof, by any disagreeable repercussions, we may take notice of a very curious provision in those little protuberances, called the tragus and antitragus of the outward ear, of a commodious form and texture (*f*), and conveniently lodged for this use. The great convenience and benefit of this form and contrivance of the outward ear, is sufficiently manifest by the want thereof, which causeth a 'confusion in the hearing, with a certain murmur, or swooning, like the fall of waters (*g*).'

Another wise provision of the Creator, is in the substance of the outward ear, which is cartilaginous, the fittest for this place. For as an ingenious anatomist (*h*) observes, 'If it had been bone, it would have been troublesome, and might, by many ac-

which hearkens strait forward, it is produced behind, for the taking of a forward sound. Whereas in a hare, which is very quick of hearing, and thinks of nothing but being pursued, it is supplied with a bony tube, which, as a natural otoconustic, is so directed backward, as to receive the smallest and most distant sound that comes behind her.' Grew's Cosmolog. Saer. l. 1. c. 5. sect. 6.

(*f*) The texture of the tragus and antitragus is softer than that of the helix, which serveth gently to blunt, not forcibly to repel, the sound in the concha.

(*g*) Dr Gibson's anatomy, chap. 22. book iii.

'Those whose ears are cut off, have but a confused way of hearing, and are obliged either to form a cavity round the ear with their own hands, or else to make use of a horn, and apply the end of it to the inner cavity of the ear, in order to receive the agitated air. It is likewise observed, that those whose ears jut out, hear better than flat-eared persons.' Monsieur Dionis's Anat. Demonst. 8.

(*h*) Gibson, Ibid.

accidents, have been broken off; if flesh, it would have been subject to contusion.' But indeed a worse consequence than this would have ensued such a softness as that of flesh, and that is, it would neither have remained expanded, neither would it so kindly receive and circulate the sounds, but absorb, retard, or blunt their progress into the inward organ. But being hard, and curiously smooth and tortuous, sounds find an easy passage, with a regular volutation and refraction; as in a well built arch, grotto, or musical instrument, which magnify and meliorate sounds; and some of which convey even a whisper to a large distance (i). But from the outward, let us carry our survey,

2. To the inward part of this admirable organ. And here we find the most curious and artful provision for every emergency and occasion. The auditory passage, in the first place, curiously tunneled, and artfully turned, to give sounds an easy passage, as well as a gentle circulation and refraction; but

(i) It would nauseate the reader to reckon up the places famed for the conveyance of whispers, such as the prison of Dionysius at Syracuse, which is said to increase a whisper to a noise; the clapping one's hands to the sound of a cannon, etc. Nor the Aqueducts of Claudius, which carry a voice sixteen miles, and many others both ancient and modern. If the reader hath a mind to be entertained in this way, he may find enough in Kircher's Phonurgia. But it may not be irksome to mention one or two of our own in England. Among which, one of the most famed is the whispering place in Gloucester cathedral, which is no other than a gallery above the east end of the choir, leading from one side thereof to the other. It consisteth, if I mistake not, of five angles, and six sides, the middlemost of which is a naked, uncovered window, looking into a chapel behind it. I guess the two whisperers stand at about twenty-five yards distance from one another. But the dome of St Paul's, London, is a more considerable whispering-place, where the ticking of a watch, when no noise is in the streets, may be heard from side to side; yea, a whisper may be sent all round the dome. And not only in the gallery below, but above, upon the scaffold, I tried, and found that a whisper would be carried over one's head round the top of the arch, notwithstanding there is a large opening in the middle of it, into the upper part of the dome.

withal, so as to prevent their too furious rushing in, and assailing the more tender parts within.

And forasmuch as it is necessary that this passage should be always open, to be upon the watch (*k*); therefore to prevent the invasion of noxious insects, or other animals, (who are apt to make their retreat, in every little hole), nature hath secured this passage (*l*), with a bitter nauseous excrement (*m*), afforded from the glands (*n*) appointed for that purpose.

(*k*) 'Auditus autem semper patet; ejus enim sensu etiam dormientes egemus: a quo cum sonus est acceptus, etiam e somno excitamur. Flexuosum iter habet, ne quid intrare possit, si simplex, et directum pateret; provisum etiam, ut siqua minima bestiola conaretur irrumperere, in sordibus aurium, tanquam in visco, inhaeresceret.' Cic. de Nat. Deor. l. 2. c. 57.

It deserves a particular remark here, that in infants in the womb, and newly born, the meatus auditorius is shut up very closely, partly by the constriction of the passage, and partly by a glutinous substance, whereby the tympanum is guarded against the water in the secundine, and against the injuries of the air as soon as the infant is born.

(*l*) It is remarkable, that in most, if not all animals, whose ears are tunneled, or where the meatus auditorius is long enough to afford harbour to ear-wigs, or other insects; that, I say, in the ears of such, ear-wax is constantly to be found. But in birds, whose ears are covered with feathers, and where the tympanum lies but a little way within the skull, no ear-wax is found, because none is necessary to the ears so well guarded, and so little tunneled.

(*m*) The ear-wax was thought, by the old anatomists, to be an excrement of the brain: 'Humor biliosus a cerebro expurgatus,' the Bartholines say of it, l. 3. c. 9. But as Schellhammer well observes, 'Nil absurdius, quam cerebri excrementum hoc statuere. Nam et ratio nulla suadet, ut in cerebro fieri excrementum tale credamus: — neque viae patent per quas ab eo seclusum in meatum auditorium possit inde penetrare.' As to its taste, Casserius gives instances of its being sweet in some creatures. But Schellhammer says, 'Ego vero semper, cum amaritiae aliquid dulcedinis in illo deprehendi.' Vide Schell. de Audit. p. 1. c. 2. sect. 10. But I could never distinguish any sweetness in it; but think it insipid mixed with a bitterness.

(*n*) 'Cerumina amara arterioli exudantia.' Willis de Anim. Brut. par. 1. c. 14. 'In the skin—are little glands, which furnish a yellow and bitter humour.' Monsieur Dionis's Dem. 13. A handsome cut of those glandulae ceruminosae is in Dr Drake, from Valsalva.

From hence let us approach the most inward parts, in which we shall see strokes of the most exquisite art. To pass over the innate air, that most authors talk of (*o*), because there is no such, the passage to the palate (*p*), and their uses, with divers other curious things that might be named; let us stop a little at the part containing the rest, namely, the bone (*q*).

Pliny attributes a great virtue to the ear-wax; 'Morsus hominis inter asperissimos numeratur: medentur sordes ex auribus: ac ne quis miretur, etiam scorpionum iustibus serpentiumque statim impositae.' Plin. Nat. Hist. l. 28. c. 4. And that it hath an healing quality, and may be accounted a good balsam, I myself have experienced.

(*o*) That there is such a thing as the innate air, talked of much by most authors on this subject, Schelhammer very justly, I think, denies; by reason there is a passage into the inner ear from the throat, through which the innate air may pass out, and the outward air enter in. Vide Par. Alt. p. 2. c. 1. sect. 10. When by stopping our breath, and straining, we force the external air into the ear, it may be heard rushing in; and if much be forced in, it may be felt also to beat against the tympanum. When the passage to the throat is by any means stopped, as by a cold in the head, etc. the hearing thereby becomes dull and blunt; by reason the communication between the outward and inward air is obstructed: but when by strong swallowing, or such like motion of the throat, the passage is opened, we perceive it by a sudden smack or crack, and we immediately hear very clearly; the load of feculent air being at that time discharged from the inner ear.

It is a wise provision, that the passage for the air into the ear, is from the throat; 'Ut non statim quivis aer externus irumpere queat (as Schelhammer saith, par. ult. cap. 4. sect. 8.) sed non nihil immutatus, ac temperatus, calore ex medio ventre exirante; imo fortassis non facile alius, nisi ex pulmonibus.'

(*p*) Valsalva hath given us a more accurate description of the tuba Eustachiana, or passage to the palate, than any other author; to whom I therefore refer, De Aur. Human. c. 2. sect. 16, etc.

The chief use hereof, he thinks, is to give way to the inner air, upon every motion of the membrana tympani, the malleus, incus, and stapes. This passage, if it be shut up, deafness ensues: of which he gives two instances: one a gentleman, who lost his hearing by a polypus in the nose reaching to the uvula; the other a yeoman, labouring with an ulcer above the left side of the uvula; which when he stopt with a tent dipped in medicine, he lost his hearing in the left ear, and recovered it, as soon as the tent was out. Ibid. cap. 5. sect. 10.

(*q*) 'Os [petrosum] ex quo interiores [labyrinthi] cavitatum parietes conflati sunt, album, durissimum, necnon maxime com-

The particular texture and hardness of which, above other bones of the body, is very remarkable; whereby it serves not only as a substantial guard to the sensory, but also to oppose the impulses of the aetherial matter, that there may be no loss nor confusion in the sound; but that it may be conveyed regularly, and entirely to the auditory nerves.

The next part I shall take notice of, may be that fine membrane called the tympanum, or membrana tympani (*r*), with its inner membrane (*f*); together with the four little appendant bones (*s*), and the

‘ pactum. Id autem a natura ita comparatum esse videtur, ut
 ‘ materia aetherea sonorum objectorum impressionibus onusta,
 ‘ dum praedictis impingitur parietibus, nihil aut saltem fere nihil
 ‘ motus sui amittat, atque adeo illum qualem ab objectis sonoris
 ‘ accepit, talem communicet spiritui animali contento intra expan-
 ‘ siones rami mollioris nervorum auris.’ Dr Raym. Vieussens of
 Montpellier, in Phil. Transf. No. 258.

(*r*) The tympanum of the ear, or, as Valsalva and the moderns, the membrani tympani, was taken notice of as early as Hippocrates's time. In birds, it is strained towards the outward parts; in other animals towards the brain, or inner parts. Monsieur Dionis saith, ‘ It is not equally fastened to the whole circumference of the bony circle, in which it is incased; for on the upper side it hath a free disengaged part, by which some can give vent to the smoke in their mouth.’ Demon. 8. That there is some passage I doubt not, but I question whether monsieur Dionis ever saw the disengaged part he mentions. I have myself carefully searched divers subjects, and do not remember to have seen any such passage; and I perceive it escaped the diligent Schelhammer's eye. Valsalva also, by injecting in through the tuba Eustachiana, could not force any liquor into the meatus auditorius; but yet he imagines he found the passage out in another place of the drum, in some morbid, and one sound head. Valsalv. de Aur. Hum. cap. 2. sect. 8. Mr Cowper also affirms there is a passage by the upper part of the membrane. Anat. Ap. fig. 8.

(*f*) Dr Vieussens, before named, discovered a membrane, tenuissimae rareque admodum texturae intra cavitatem tympani;’ as he describes it. Whose use he saith is, 1. ‘ Occludens labyrinthi januam impedit ne naturalis purissimus ac subtilissimus aer intra cavitates—communicationem---habeat cum aere craffo. 2. Labyrinthi basin calefacit, etc. ubi supra.’ Probably this double membrane may be such, or after the same manner as it is in the tympanum of birds: of which see my observations in book vii. chap. 2. note (*e*).

(*s*) The four little bones being treated of by all that have com-

three inner muscles to move them, and adjust the whole compages to the several purposes of hearing, to hear all manner of sounds, loud or languid, harsh or grateful (*t*).

cerned themselves about this sense of hearing, since their discovery, I shall take notice of only two things concerning them. 1. The discovery of them is owing wholly to the diligence and sagacity of the latter ages; of which Schelhammer gives this account from Fallopius: 'Haec officula antiquis anatomicis---ignota fuere; primusque qui in lucem produxit [malleum et incudem] fuit Jac. Carpenis; primus quoque procul omni dubio anatomicae artis, quam Vesalius postea perfecit, restaurator. Tertium [stapedam] invenit ac promulgavit primus Joh. Phil. ab Ingrassia, Siculus, philosophus, ac medicus doctissimus. Quartum, Thoma Bartholino teste, viro longe celeberrimo, Fran. Sylvio debetur.' Schel. ubi supra. Cap. 3. sect. 9. 2. Their difference in animals: in man and quadrupeds, they are four, curiously inarticulated with one another; with an external and internal muscle to draw, or work them, in extending, or relaxing the drum; but in fowls the case is very different: 'His unum officulum solum largita est natura, quod mobilis, quae in tympanum videtur terminari.' Id. ib. sect. 8. Collumellam forte appellaveris: teres enim est et subtilissimum, basi innitens latiori, rotundae. Huic adnexa est cartilago valde [mobilis]. In the ears of all the fowl that I could examine, I never found any more than one bone, and a cartilage making a joint with it, that was easily moveable. The cartilage had generally an epiphyse, or two, one on each side—The bone was very hard and small, having at the end of it a broad plate, of the same substance, very thin, upon which it rested as on its basis.' Dr Al. Moulen in Phil. Trans. No. 100.

These are the most material things I find observed by others, concerning the ears of fowls, and some of them hardly, I believe, observed before. To which I shall subjoin some other things I have myself discovered, that I presume escaped the eyes of those most curious and inquisitive anatomists. Of which see the last cited book vii. chap. 2. note (*e*).

(*t*) 'Videtur quod tympanum auditionis instrumentum praeliminare, et quasi praeparatorium fuerit, quod soni impressionem sive species sensibiles primo suscipiens, eas in debita proportionem, et apta conformitate versus sensorium, quod adhuc interius situm est, dirigat: simili officio fungitur respectu auditus, tunicae oculi pupillam constituentes, respectu visus; utraque membranae species sensibiles refringunt et quasi emolliunt, easque sensorio non nisi proportionatas tradunt, cui nudo si adveniant teneriorem ejus crasin facile laedant, aut obruant. Reversum tympanum non audit, sed meliori tutiorque auditioni confertur. Si haec pars destruat, sensus adhuc aliquamdiu, rudi licet modo, peragi possit; quippe experimento olim in cane facto, etc.

From this region of the tympanum, I might pass

—Janitoris officio ut tympanum recte defungi possit, expansum ejus pro data occasione stringi, aut relaxari debet, veluti nimirum oculi pupilla—Quapropter huic auris tympano, non secus ac bellico, machinae sive taeniae quaedam apponuntur, quae superficiem ejus modo tensioem, modo laxiorem reddant: hoc enim efficiunt tria ossicula, cum musculo,' etc. Willis de An. Brut. c. 14.

For this opinion of Dr Willis, Dr Schelhammer is very severe upon him, deriding the refractions he speaks of; and therefore seriously proves, that they are the humours, not tunics of the eye, that refract the rays of light; and then jeeringly demandeth, whether the sonorous rays are refracted by passing through a different medium? whether the convexity or concavity of the drum collects those rays into a focal point, or scatters them? etc. And then saith, 'Ob has rationes a clariss. viri, ac de re medica praeclare meriti, sententia non possumus non esse alieniore; in quo uti ingenium admiror, quoties medicamentorum vires, aut morborum causas explicat, sic ubi forum suum egressus, philosophum agit, ac vel partium usum, vel chymicarum rerum naturam scrutetur, ejus haud semel non modo judicium desidero, verum aliquando etiam fidem.' This is so severe and unjust a censure of our truly famous countryman, a man of known probity, that might deserve a better answer; but I have only time to say, that although Dr Schelhammer hath out-done all that wrote before him, in his book de Auditu, and shewed himself a man of learning and industry; yet as our countryman wrote more than he, though perhaps not free from errors too, so he hath manifested himself to have been as curious and sagacious an anatomist, as great a philosopher, and as learned and skilful a physician, as any of his censurers, and his reputation for veracity and integrity, was no less than any of theirs too. But after all this terrible clamour, Dr Schelhammer prejudicately mistaketh Dr Willis's meaning, to say no worse. For, by 'utraque membranae refringunt,' Dr Willis plainly enough, I think, means no more than restriction of the ingress of too many rays; as his following explicatory words manifest, viz. 'refringunt, et quasi emolliunt, easque sensorio non nisi proportionatas tradunt.' But indeed Dr Schelhammer hath shewn himself a too rigid censor, by making Dr Willis say, the ear-drum hath such like braces as the war-drum, viz. 'Quod porro de machinis seu taeniis tympani bellici adducit, dicitque idem in tympano auditorio conspici, id propter falsissimum est.' I wonder Dr Schelhammer did not also charge Dr Willis with making it a porter, since he hath in the same paragraph, 'janitoris officio,' etc. But Dr Willis's meaning is plain enough, that the little bones and muscles of the ear-drum do the same office in straining and relaxing it, as the braces of the war-drum do in that. And considering how curious and solemn an apparatus there is of bones, muscles, and joints, all adapted to a ready motion, I am clearly of Dr Willis's opinion,

that one great use of the ear-drum is for the proportioning sounds, and that by its extension and refraction, it corresponds to all sounds, loud or languid, as the pupil of the eye doth to several degrees of light: and that they are no other than secondary uses assigned by Dr Schelhammer, as the principal or sole uses of keeping out the external colder air, dust, and other annoyances; but especially that, 'Ob solius aeris interni potissimum irrumpentis vim, hunc motum tympani ac mallei esse conditum, ut cedere primum, deinde sibi restitui queat;' as his words are, p. ult. c. 6. sect. 13.

It was no improbable thought of Rohault, 'Nos attentos praebere, nil aliud est, nisi tympanum, ubi ita opus est facto, contendere aut laxare, et operam dare ut illud in ea positione intentum stet, in qua tremulum aeris externi motum commodissime excipere possit.' Roh. Phys. p. 1. c. 26. sect. 48.

The hearing of deaf persons more easily by means of loud noises, is another argument of the use of the straining or relaxation of the tympanum in hearing. Thus Dr Willis, ubi supra, 'Accepi olim a viro fide digno, se mulierem novisse, quae licet surda fuerit, quousque tamen intra conclave tympanum pulsaretur, verba quaecvis clare audiebat: quare maritus ejus tympanum tam pro servo domestico conducebat, ut illius ope, colloquia interdum cum uxore sua haberet. Etiam de alio furdastro mini narratum est, qui prope Campanile degens, quoties una plures Campanae resonarent, vocem quamvis facile audire, et non ali- as, potuit.'

'Abscisso musculo [processus majoris mallei] in recenti auro, relaxatur [tympani membrana].' Valsa. de Aur. Hum. c. 2. sect. 5.

Upon considering the great difference in authors opinions, about the use of the parts, and manner how hearing is performed, as also what a curious provision there is made in the ear, by the four little bones, the muscles, membrane, etc. I was minded, since I penned this note, to make inquiry myself into this part, and not to rely upon authority. And after a diligent search of various subjects, I find we may give as rational and easy an account of hearing, as of seeing, or any other sense; as I have shewn in my last cited note (c), book vii. chap. 2. with relation to birds. And as to men and beasts, the case is the same, but the apparatus more complex and magnificent. For whereas in birds, the auditory nerve is affected by the impressions made on the membrane, by only the intermediacy of the columella; in man, it is done by intervention of the four little bones, with the muscles acting upon them; his hearing being to be adjusted to all kinds of sounds, or impressions made upon the membrane of the tympani. Which impressions are imparted to the auditory nerve, in this manner, viz. first they act upon the membrane and malleus, the malleus upon the incus, and the incus upon the os orbiculare and stapes; and the stapes upon the auditory nerve: for the base of the stapes (the same as the operculum in birds) not only covers the fenestra ovalis, within which the auditory nerve

to that of the labyrinth (*u*), and therein survey the curious and admirable structure of the vestibulum, the semicircular canals (*v*), and cochlea; particularly the artificial gyrations, and other singular curiosities observable in the two latter.

But I shall not expatiate on these reclusive parts; only there is one special contrivance of the nerves ministering to this sense of hearing, which must not be passed by; and that is, the branches of one of the auditory nerves (*w*), spread partly to the muscles of

lieth, but hath a part of the auditory nerve spread upon it too. It is manifest that this is the true process of hearing; because if the membrane be moved, you may see all the bones move at the same time, and work the base of the stapes up and down in the fenestra ovalis, as I shewed in this chapter, note (*d*), p. 135. concerning the mole; and as it may be seen in other ears carefully opened, if the parts remain in situ.

(*u*) I do not confine the labyrinth to the canales semicirculares, or any other part, as the elder anatomists seem to have done, who by their erroneous and blind descriptions seem not well to have understood these parts; but with those much more curious and accurate anatomists, monsieur de Verney, and Dr Valsalva, under the labyrinth, I comprehend the canales semicirculares, and the cochlea, together with the intermediate cavity, called by them the vestibulum.

(*v*) In the semicircular canals, two things deserve to be noted. 1. That the three canals are of three different sizes, major, minor, and minimus. 2. Although in different subjects they are frequently different; yet in the same subject they are constantly the same. The reason of all which, together with the uses, Valsalva ingeniously thinks is, that as a part of the tender auditory nerve is lodged in these canals, so they are of three sizes, the better to suit all the variety of tones; some of the canals suiting some, and others, other tone. And although there be some difference as to the length and size of these canals, in different persons; yet lest there should be any discord in the auditory organs of one and the same man, those canals are always in exact conformity to one another in one and the same man. Vide Valsal. ubi supra, cap. 3. sect. 7. and cap. 6. sect. 4. 9.

(*w*) Hic posterior nervus extra cranium delatus, in tres ramos dividitur, qui omnes motibus patheticis—inserviunt. Primus—musculis auris impenditur. Procul dubio hujus actione efficitur, ut animalia quaevis, a subito soni impulsu, aures quasi sonum nimis cito transeuntem captaturas erigant. Ramus alter—versus utrumque oculi angulum surculos emittit: qui musculis palpebrarum attollentibus inferuntur; quorum certe munus est ad subitum soni appulsum oculos confellim aperire, eosque velut ad excubias vocare.—Tertius—ramus versus linguae ra-

the ear, partly to the eye, partly to the tongue and instruments of speech, and inoculated with the nerves to go to the heart and breast, by which means there is an admirable and useful consent between these parts of the body; it being natural for most animals upon the hearing any uncouth sound, to erect their ears, and prepare them to catch every sound; to open their eyes (those constant faithful centinels) to stand upon their watch; and to be ready with the mouth to call out, or utter what the present occasion shall dictate. And accordingly it is very usual for most animals, when surprized, and terrified with any noise, presently to shriek and cry out.

But there is besides this, in man, another great use of this nervous commerce between the ear and the mouth; and that is, as one of the best authors on this subject expresseth it (x), 'That the voice may correspond with the hearing, and be a kind of echo thereof, that what is heard with one of the two nerves, may be readily expressed with the voice by the help of the other.'

Thus much may suffice to be said concerning the organ. Let us,

II. Take notice of the object of this admirable sense, namely, sound; and so conclude this chapter. I shall not here inquire into the nature and properties of sound, which is in a great measure intricate, and hath puzzled the best naturalists: neither will I shew how this admirable effect of the divine contrivance may be improved to divers uses (y) and purposes in

'dicem descendens, musculis ejus et ossis hyoideos distribuitur, & deoque organa quaedam vocis edendae aëuat,' etc. Will. Cer. An. 2. c. 17.

(x) 'Hujusmodi nervorum conformatio in homine usum alium insigniorem præstat, nempe ut vox,' etc. Willis, ibid.

(y) Among the uses to which the wit of man hath employed sounds, we may reckon the instruments useful in convocating assemblies, managing armies, and many other occasions, wherein bells, trumpets, drums, horns, and other sounding instruments are used; the particulars of which it would be tedious to recount:

human life; but my business will be to shew that this thing, of so admirable use in the animal world, is the work of God. And this will appear, let the subject matter of sounds be what it will; either the

as that the biggest bell in Europe is reckoned to be at Erfurt in Germany, which they say may be heard twenty-four miles; with much more to the same purpose. I shall therefore only for a sample take notice of the speaking-trumpet; the invention of which is commonly ascribed to our eminent Sir Samuel Morland; but was more probably Ath. Kircher's; at least he had contrived such an instrument, before Sir Samuel hit upon his. Kircher in his *Phonurg*, saith, the Tromba published last year in England, he had invented twenty-four years before, and published in his *Misurgia*; that Jac. Albanus Ghibbescius, and Fr. Eschinardus ascribe it to him; and that G. Schottus testifieth he had such an instrument in his chamber in the Roman College, with which he could call to, and receive answers from the porter. And considering how famed Alexander the Great's tube was, which is said might be heard 100 stadia, it is somewhat strange that no body sooner hit upon the invention. Of this Stentorophonic horn of Alexander, there is a figure preserved in the Vatican, which, for curiosity sake, I have from Kircher represented in fig. 3. He saith its diameter was five cubits, and that it was suspended on a supporter.

For the make of the speaking-trumpet, and the reason why it magnifies sounds, I shall refer to Kircher; especially to Sir Samuel Morland's *Tuba Stentorophonica*, published in 1672.

Kircher saith, he took one of these trumpets of fifteen palms length, along with him to the Mons Eustachianus, where he convoked 2200 persons to prayers, by means of the unusual sound, at two, three, four, and five Italian miles distance.

With these bellowing-trumpets, I shall join some bellowing caves for the reader's diversion. Ol. Magnus describes a cave in Finland, near Viburgh, called Smellen, into which, if a dog, or other living creature be cast, it sends forth so dreadful a sound, that knocks down every one near it. For which reason they have guarded the cave with high walls, to prevent the mischiefs of its noise. Vide Ol. Magn. Hist. l. 11. c. 4. Such another Peter Martyr saith is in Hispaniola, which with a small weight cast into it, endangers deafness at five miles distance. And in Switzerland, Kircher saith, in the Cucumer-Mountains is a pit that sends out both a dreadful noise and a great wind therewith; and that there is a well in his country 3000 palms deep, whose sound is equal to that of a great gun. Vide Kirch. *Phonurg*.

Ol. Magnus speaking of the vast high mountains of a northern province, called Angermannia, saith, 'Ubi bases eorum in profundissimo gurgite stantes, casu aliquo, vel propositio nautae accesserint, tantum horrorem ex alta fluctuum collisione percipiunt, ut nisi praecepiti remigio, aut valido vento evaserit,

atmosphere (z) in gross, or the ætherial part thereof, or soniferous particles of bodies, as some fancy, or whatever else the philosophers may think it. For,

* solo pavore fere exanimés fiant, multoque dierum curriculo,
 * ob capitis turbationem, pristinae mentis, et sanitatis compotes
 * vix evadant. Habent bases illorum montium in fluctum in-
 * gressu et regressu tortuosas rimas, sive scissuras, satis stupendo
 * naturae opificio fabricatas, in quibus longa voragine, formida-
 * bilis ille sonitus quasi subterraneum tonitru generatur. Ol.
 Magn. l. 2. c. 4. See also chap. 12.

(z) That the air is the subject, or medium of sound, is manifest from the experiments in rarified and condensed air. In an unexhausted receiver, a small bell may be heard at the distance of some paces: but when exhausted, it can scarce be heard at the nearest distance; and if the air be compressed the sound will be louder, proportionably to the compression or quantity of air crouded in, as I have often tried myself, and may be seen in Mr Hawksbee's curious experiments, p. 97. Also his experiments in Phil. Transf. No. 321.

Neither doth this succeed only in forced rarefractions and condensations of the air, but in such also as are natural; as is evident from David Froedlichius in Varenius, upon the highest eminences of Carpathus, near Kesmarck in Hungary. The story of Froedlichius is this, 'Ego mense Junii 1615, tum adolescentens, sublimitatem horum montium, cum duobus comitibus scholaribus, experiri volens, ubi, cum in primae rupis vertice, magno labore, me summum terminum assecutum esse putarem, demum sese obtulit alia multo altior cautes, ubi per vasta caeque vacillantia saxa (quorum unum, si loco a viatore dimoveretur --- aliquot centena---rapit, et quidem tanto cum fragore, ut illi metuendum sit ne totus mons corruat, eumque obruat) enixus essem, iterum alia sublimior prodiit, etc. donec summo vitae periculo ad supremum cacumen penetraverim. Ex declivioribus montibus cum in subjectas valles, ---nil nisi obscuram noctem, aut coeruleum quid, instar profundi aeris, quod vulgo sudum coelum appellatur, observare potui mihiq; videbar, si de monte caederem, non in terram, sed recte in solem me prolapsum. Nimia enim declivitate, species visibiles extenuatae et hebetatae fuerunt. Cum vero altioremontem peterem, quasi intra nebulas densissimas haerebam---Et cum non procul a summo vertice essem, de sublimi quiescens prospexi et animadverti iis in locis, ubi mihi antea videbar intra nebulas haesisse, compactas atque albas sese movere nubes, supra quas, per aliquot milliaria, et ultra terminos Sepusi commodus mihi prospectus patuit. Alias tamen etiam nubes altiores, alias item humiliores, necnon quasdam aequaliter a terra distantes vidi. Atque hinc tria intellexi, 1. Me tum transivisse principium mediae aeris regionis. 2. Distantiam nubium a terra, non esse aequalem---3. Distantiam nubium---non 72 mill. Ger. ut

who but an intelligent being, what less than an omnipotent and infinitely wise God could contrive, and make such a fine body, such a medium, so susceptible of every impression, that the sense of hearing hath occasion for, to empower all animals to express their sense and meaning to others; to make known

‘quidam --sed tantum dimidiatum mill. Ger. In summum montis verticem cum pervenissem, adeo tranquillum et subtilem aerem ibi offendi, ut ne pili quidem motum sentirem, cum tamen in depressioribus ventum vehementem expertus sim: unde collegi summum cacumen istius montis Carpathici ad mill. Germ. a radicibus suis imis exsurgere, et ad supremam usque aeris regionem, ad quam venti non ascendunt, pertingere. Explosi in ea summitate sclopetum: quod non majorem sonitum primo prae se tulit, quam si tigillum vel bacillum confregissem; post intervallum autem temporis murmur prolixum invaluit, inferioresque montis partes, convalles et sylvas opplevit. Descendendo per nives annosas intra convalles, cum iterum sclopetum exonerarem, major et horribilior fragor, quam ex tormento capacissimo inde exoriebatur: hinc verebar ne totus mons concussus mecum corrueret: duravitque hic sonus per semiquadrantem horae, usque dum abstrusissimas cavernas penetrasset, ad quas aer undique multiplicatus resiliit.-- In his celsis montibus, plerumque ningit grandinatae media aestate, quoties nempe in subjecta et vicina planitie pluit, uti hoc ipsum expertus sum. Nives diversorum annorum ex colore et cortice dure dignosci possunt.’ Varen. Geogr. l. 1. c. 19. prop. ult.

The story being diverting, and containing divers things remarkable, I have chosen to note the whole of it, although somewhat long, rather than single out the passages only which relate to the diminishing the sound of his pistol, by the rarity of the air at that great ascent into the atmosphere; and the magnifying the sound by the polyphonisms or repercussions of the rocks, caverns, and other phonocampic objects below in the mount.

But it is not the air alone that is capable of the impressions of sound, but the water also, as is manifest by striking a bell under water, the sound of which may plainly enough be heard, but it is much duller, and not so loud; and it is also a fourth deeper by the ear of some great judges in musical notes, who gave me their judgements in the matter. But Mercenne saith, a sound made under water, is of the same tone or note, if heard under water, as are also sounds made in the air, when heard under water. Vide Mersen. Hydraul.

Having mentioned the hearing of sounds under water, there is another curiosity worth mentioning, that also farther proves water to be susceptible of the impressions of sound, viz. divers at the bottom of the sea can hear the noises made above, only confusedly. But, on the contrary, those above cannot hear the di-

their fears, their wants, their pains, and sorrows in melancholic tones; their joys and pleasures in more harmonious notes; to send their minds at great distances (*aa*), in a short time (*bb*), in loud boations; or

vers below. Of which an experiment was made, that had like to have been fatal: one of the divers blew an horn in his diving-bell, at the bottom of the sea; the sound whereof, in that compressed air, was so very loud and irksome, that stunned the diver, and made him so giddy, that he had like to have dropt out of his bell, and to have been drowned. Vide Sturmii Colleg. Cur. vol. 2. tentam. 1.

(*aa*) As to the distance to which sound may be sent, having some doubt, whether there was any difference between the northern and southern parts, by the favour of my learned and illustrious friend Sir Henry Newton, her late majesty's envoy at Florence, I procured some experiments to be made for me in Italy. His most serene highness the great duke was pleased to order great guns to be fired for this purpose at Florence, and persons were appointed on purpose to observe them at Leghorn, which they compute is no less than 55 miles in a strait line. But notwithstanding the country between being somewhat hilly and woody, and the wind also was not favouring, only very calm and still, yet the sound was plainly enough heard. And they tell me, that the Leghorn guns are often heard 66 miles off, at Porto Ferraro; that when the French bombarded Genoa, they heard it near Leghorn, 90 miles distant; and in the Messina insurrection, the guns were heard from thence as far as Augusta and Syracuse, about 100 Italian miles. These distances being so considerable, give me reason to suspect, that sounds fly as far, or nearly as far, in the southern as in the northern parts of the world, notwithstanding we have a few instances of sounds reaching farther distances. As Dr Hearn tells us of guns fired at Stockholm in 1685, that were heard 180 English miles. And in the Dutch war, 1672, the guns were heard above 200 miles. Vide Phil. Trans. No. 113. Also there is this farther reason of suspicion, that the mercury in the barometer riseth higher without than within the tropics, and the more northerly, still the higher, which may increase the strength of sounds, by note (*z*), p. 148.

(*bb*) As to the velocity of sounds, by reason the most celebrated authors differ about it, I made divers nice experiments myself, with good instruments; by which I found, 1. That there is some, although a small difference, in the velocity of sounds, with or against the wind; which also is, 2. Augmented or diminished by the strength or weakness of the wind. But that nothing else doth accelerate or retard it, not the differences of day or night, heat or cold, summer or winter, cloudy or clear, barometer high or low, etc. 3. That all kinds of sounds have the same motion, whether they be loud or languid, of bells, guns,

to express their thoughts near at hand with a gentle voice, or in secret whispers! And, to say no more, who less than the same most wise and indulgent Creator could form such an œconomy, as that of melody and music is: that the medium should, as I said, so readily receive every impression of sound, and convey the melodious vibration of every musical string, the harmonious pulses of every animal voice, and of every musical pipe; and the ear be as well adapted, and ready to receive all these impressions, as the medium to convey them: and lastly, that by means of the curious lodgement, and inoculation of the auditory nerves before mentioned, the orgasms of the spirits should be allayed, and perturbations of the mind, in a great measure quieted and stilled (cc): or,

great or small, or any other sonorous body. 4. That they fly equal spaces in equal times. 5thly and lastly, That the mean of their flight is at the rate of a mile in 9 half seconds and a quarter, or 1142 feet in one second of time. Vide Phil. Transf. ibid.

(cc) Timothy a musician could excite Alexander the Great to arms with the Phrygian sound, and allay his fury with another tone, and excite him to merriment. So Ericus king of Denmark, by a certain musician, could be driven to such a fury, as to kill some of his best and most trusty servants. More of this power of music over the affections, may be seen in Ath. Kirch. Phonurg. lib. 2. sect. 1. Also in Ic. Vossius de Poematum cantu et Rythmi viribus.

And not only upon the affections, but also on the parts of the body, music is able to exert its force, as appears from the Gascoigne knight, 'Cui Phormingis sono audito Vesica statim ad urinam reddendum vellicabatur.' Such another we have in Ao. 1. Ephem. Nat. Curios. Obser. 134. Also Morhoff de Scyph. vitri per cert. human. vocis sonum fracto: where there is not only the account of the Dutchman at Amsterdam, one Nich. Peter, that brake Romer glasses with the sound of his voice, but also divers other instances of the powers and effects of sound. But to the story of the Gascoigne knight, Mr Boyle, from Scaliger, adds a pleasant passage, that one he had disobliged, to be even with him, caused at a feast, a bag pipe to be played, when he was hemmed in with the company; which made the knight bepiss himself, to the great diversion of all then present, as well as confusion of himself. Boyle's Essay of the effect of Lang. Motion. In the same book are other matters that may be noted here. One whose arm was cut off, was exceedingly tormented with the discharge of the great guns at sea, although he was at a great distance on land. And a great ship-commander observed

to express it in the words of the last cited famous author (*dd*), ' That music should not only affect the

his wounded men, with broken limbs, suffered in like manner at the enemies discharges. An ingenious domestic of his own would have his gums bleed at tearing of brown paper. And an ingenious gentleman of Mr Boyle's acquaintance confessed to him, that he was inclined to the knight of Gascoigne's distemper, upon hearing the noise of a tap running. The dancing to certain tunes, of persons bit with the tarantula, he was assured of by an ingenious acquaintance at Tarentum, who saw several, among the rest a physician, affected with that distemper. And many other accounts of this kind, seemingly credible, are related in Morhoff, Kircher, and many others; although Dr Cornello questions the matters of fact relating to the cure of the tarantula bite, in Phil. Transf. No. 83. Mr Boyle also saith, a sober musician told him, he could make a certain woman weep, by playing one tune, which others would be little affected at. And he saith, that he himself had a kind of shivering at the repeating two verses in Lucan. And I add, that I very well know one to have a sort of chill about his praecordia and head, upon reading or hearing the 53d chapter of Isaiah; as also David's lamentations for Saul and Jonathan, 2 Sam. i.

Neither are our own minds and bodies only affected with sounds, but inanimate bodies are so also. Of which many stories may be met with in Kircher, particularly a large stone that would tremble at the sound of one particular organ-pipe; in Morhoff also, who among many other relations hath this, ' *Memini cum ip[s]i [clerici Willisii] de experimento vitri per vocem fracti raritatem, ex eo audivisse, quod in aedibus musicis sibi vicinis aliquoties collapsum pavimentum fuerit; quod ipse sonis continuis adscribere non dubitavit.*' Morhoff. c. 12. Mersenne also, among many relations in his Harmon. and other books, tells a far more probable story, of a particular part of a pavement, that would shake, as if the earth would open, when the organs played, than what he relates about Antipathy, in his Quaest. comment. in Genes. viz. that the sound of a drum made of a wolf's skin, will break another made of sheep's skin: that hens will fly at the sound of a harp strung with fox-gut-strings, and more to the same purpose. Mr Boyle also, in his last cited book tells us, seats will tremble at the sound of organs; and that he hath felt his hat to do so too under his hand, at certain notes both of organs, and in discourse; that he tried an arch that would answer to c-fa-ut, and had done so 100 years; and that an experienced builder told him, any well built vault will answer some determinate note. And at Eastbury-house near Barking, I myself discovered the porch, having firm brick walls, not only to sound when struck on the bottom, but also to give almost as loud a sound, when I sounded the same note with my voice.

(*dd*) Willis, ubi supra.

‘fancy with delight, but also give relief to the grief
‘and sadness of the heart; yea, appease all those
‘turbulent passions, which are excited in the breast
‘by an immoderate ferment, and fluctuation of the
‘blood.’

And now, who can reflect upon all this curious apparatus of the sense of hearing, and not give the great Creator his due praise! Who can survey all this admirable work, and not as readily own it to be the work of an omnipotent, and infinitely wise and good God (*ee*), as the most artful melodies we hear, are the voice or performances of a living creature!

C H A P. IV.

Of the Sense of S M E L L I N G.

THIS sense I shall dispatch in less compass than the two last, because its apparatus (although sufficiently grand and admirable, yet) is not so multiplicitious as of the eye and ear; it being sufficient in this sense, that the odoriferous effluvia of bodies (*a*) can have an easy, free passage to the olfactory nerves, without the formalities of refractions, and other preparations necessary to the perfection of the two former senses. Accordingly the all-wise Creator hath made sufficient provision for the reception of smells, in the aperture of the nostrils (*b*); made not of flesh,

(*ee*) ‘Ille Deus est—qui non calamo tantum cantare, et agreste, atque inconditum carmen ad aliquam tantum oblectationem moleculari docuit, sed tot artes, tot vocum varietates, tot sonos, alios spiritu nostro, alios externo cantu edituros commentus est.’
Sec. de Benef. l. 4. c. 6.

(*a*) A piece of ambergrease, suspended in a pair of scales that had torn with a very small part of a grain, lost nothing of its weight in three days and a half; neither did assafoetida in five days and a half: but an ounce of nutmegs lost five grains and a half in six days; and cloves seven grains and four fifths. Boyle’s *Phil. of Effluv.* c. 5.

(*b*) ‘Nares, eo quod omnis odor ad superiora fertur, recte sur-

or bone, but cartilaginous, the better to be kept open, and withal, to be dilated or contracted, as there is occasion: for which service it hath several proper and curious muscles (*c*).

And forasmuch as it is by breathing (*d*), that the odorant particles are drawn in, and conveyed to the sensory; therefore there is a very wise provision made in the laminae, with which the upper part of the nose is barricaded, which serve to two excellent uses; partly, to fence out any noxious substances from entering the breathing passages in our sleep, or when we cannot be aware (*e*); and partly to receive diversifications of the olfactory nerves, which are here thick spread, and which do by these means meet the smells entering with the breath, and striking upon them.

And accordingly, the more accurate this sense is, in any animal, the longer we may observe those laminae are; and more of them in number folded up, and crouded together, to contain the more nervous filaments, and to detain and fetter the odoriferous particles in their windings and turnings.

And an admirable provision this is, which the great Creator hath made for the good of brute creatures (*f*); the chief acts of many of whose lives are

‘sum sunt: et quod cibi et potionis judicium magnum earum est, non sine causa vicinitatem oris secutae sunt.’ Cicer. de Nat. Deor. l. 2. c. 56.

(*c*) Had not the contriver of animal bodies been minded that his work should have all the signatures of accuracy, this sense might have been performed with a bare aperture of the nose; but that nothing might go imperfect out of his hand, he hath made a part of the nose easily moveable, and given a set of muscles to lift up, and open and shut the nostrils; and so adjust it to every occasion of this sense.

(*d*) ‘Odorem non aliud, quam infectum aera, intelligi posse.’ Plin. Nat. Hist. l. 9. c. 7.

(*e*) For a further guard against the ingress of noxious things the vibrissi, or hairs placed at the entrance of the nostrils serve; which, in some measure, stop the entrance of things improper, or, however, give warning of them; but at the same time allow an easy passage to the breath and odours.

(*f*) ‘Multo praeclarius emicat [olfactus] in brutis animalibus

performed by the ministry of this sense. In insects, and many other creatures, it is of great use in the propagation of their kind; as particularly in helping them to safe and convenient places for the incubation of their eggs, and breeding up their young. Others are, by the accuracy of this sense, of use to mankind, which would be otherwise of little or no use (*g*). And most of the irrational animals, birds, beasts, and creeping things, do, by their smell, find out their food; some at great distances, and some at hand. With what sagacity do some discover their food in the midst of mud and dirt (*h*)! With what curiosity do the herbacious kind pick and chuse such plants as afford them wholesome food, or sometimes such as are medicinal (*i*), and refuse such as would hurt and destroy them! And all by the help principally, if not only, of the smell, assisted by its near ally the taste. Of which I shall in the next place speak very briefly.

‘quam in homine: ista namque hoc solo indice, herbarum, aliorumque corporum prius ignotorum virtutes certissime dignoscunt, quin et victum suum absentem, vel in abstruso positum, odoratu venantur, ac facillime investigant. Quod autem minus sagaces sunt hominum nares, illud non facultatis hujus abusui, prout nonnulli volunt, ascribi debet, verum in causa est ipsius organi defectus: hoc enim circa victus humani criteria, ubi ratio, et intellectus adsunt, non ita accuratum requiritur: propterea enim inferiores potentiae in homine, a natura minus perfectae existunt, ut superiorum cultui et exercitio relinqueretur locus.’ Willis de Anim. Brut. c. 13.

(*g*) Thus the chief use of hounds is to hunt; and other dogs, to be a watch and guard to our houses by night. For which services, particularly in hounds, their olfactory nerves are not only remarkably larger, like as they are in other brutes, but their branches and filaments are, in the laminae of the nostrils, both more and larger than I have seen in any other creature whatsoever. Also there are more convulsions of the laminae than I ever remember to have found in any other animal.

The sagacity of hounds is prodigious; of which see an instance in book iv. chap. 11. note (*ddd*).

(*h*) See book vii. chap. 2. note (*g*).

(*i*) Vide Plin. Hist. Nat. l. 8. c. 27. ‘Quae animalia quas herbas ostenderunt.’

C H A P. V.

Of the TASTE (a).

IN this, as in the last sense, we have an apparatus abundantly sufficient to the sense; nerves curiously divaricated about the tongue (b), and mouth, to receive the impressions of every gusto; and these nerves guarded with a firm and proper tegument to

(a) 'Τὰ δὲ εἶδη τῶν χυλῶν etc. Saporum genera, -- dulcis, pinguis, austerus, acerbus, -- acris, salus, amarus, acidus.' Theophr. de Caus. Plant. l. 6. c. 1. What may be the cause of the difference of tastes, he saith, is hard to assign, πότερον γὰρ τοῖς πάθουσιν, etc. Utrum affectionibus sensuum -- an figuris, quibus sensus guli constant, ut Democritus censet, id. ibid. Δημόκριτος δὲ, etc. Democritus -- dulcem esse saporem qui rotundus; acerbum qui figura magna; asperum qui multis angulis,' etc. id. ib. etc. But of the diversities and causes of tastes, see Dr Grew. lect. 6. and Dr Willis de Anim. Brut. c. 12.

(b) 'Intellectus saporum est caeteris in prima lingua: homini, et in palato.' Plin. l. 11. c. 37.

The opinions of the anatomists concerning the organ of taste, are various. Bauhin. T. Bartholin. Bartholette, Vessinge, Deussinge, etc. place it in the laxer, fleshy parts of the tongue. Our famous Wharton, in the gland at the root of the tongue: Laurentius in the thick tunic covering the tongue; but the learned Malpighi with great probability concludes, because the outward cover of the tongue is perforated, under which lie papillary parts, (of which Mr Cowper hath very good cuts in his Anat. tab. 13.) that in these the taste lieth. Malpighi's words are, 'Quare cum dictis meatibus insignibus occurrant papillaria corpora, probabilis est in his ultimo, ex subintranti sapido humore titillationem et medicationem quandam fieri, quae gustum efficiat.' Malpighi Op. Tom. 2. De Lingua, pag. 18.

'Praecipuum ac fere solum Gustatus organon est lingua; cui aliquatenus, subobscurè tamen, palatum, et superior gulae pars consentiunt: in omnibus vero fibrae nervosae immediata sensationis instrumenta sunt. Quare observare est, linguam praeter alia quavis parte insigniter fibrosam esse, etiam textura valde porosa constare, in eum nempe finem, ut particulae rei sapidae copiosius ac penitus intra sensorii meatus admittantur -- Nervi autem qui fibris linguae densissime intertextis famulantur, a saporum impressiones τῷ πρῶτῳ αισθητηρίῳ communicant, sunt. -- Nervi e paribus tum quinto, tum nono; et ubique eum densa propaginum serie per totam ejus compagem distribuit' Willis ib.

defend them from harms ; but withal, so perforated in the papillary eminences, as to give a free admission to tastes.

But I shall say no more of this sense ; only a word or two of its consent with the smell, and the situation of them both : their situation is in the most convenient place imaginable, for the discharge of their offices ; at the first entrance (*c*), in the way to the grand receptacle of our food and nourishment ; to survey what is to be admitted therein ; to judge between what is wholesome, and fit for nourishment, and what is unfavoury and pernicious. And for this end, the all-wise Creator seems to have established a great consent between the eye, the nose, and the tongue, by ordering the branches of the same nerves (*d*), to each of those three parts ; as also indeed, to divers other parts of the body, which I may have occasion to mention in a more proper place (*e*) By which means, there is all the guard that can be, against pernicious food ; forasmuch as before it is taken into the stomach, it is to undergo the trial of three of the senses ; the scrutiny of the eye, the strict surveyor of its outward appearance ; and the probation of the smell and taste, the two severest judges of its natural constitution and composition.

(*c*) 'Gustatus, qui sentire eorum quibus vescimur genera debet, habitat in ea parte oris, qua esculentis et poculentis iter natura patefecit.' Cic. de Nat. Deor. l. 2. c. 56. Vide quoque supra, note (*b*), chap. iv. p. 153.

(*d*) 'Multa hujus [quinti Paris] nervi propagines masticationis operi destinantur ; ideoque quoniam alimenta ingerenda non modo gustus, sed etiam olfactus et visus examen subire debent, ab eodem nervo, cujus rami ad palatum et fauces missi, manducationis negotium peragunt, propagines aliae, velut exploratrices, ad nares et oculos feruntur, nempe ut isthaec aliorum sensuum organa, etiam ad objecta gustus melius dignoscenda probationum auxiliis quibusdam instruantur.' Willis Ner. Des. et Usus, c. 22.

(*e*) See book v. c. 8.

C H A P. VI.

Of the Sense of FEELING (a).

HAVING spent so much time upon the other senses, and therein given such ample proofs of the infinite Creator's wisdom; I shall but briefly take notice of two things relating to this last sense.

One is, its organ and nerves. For, as all sensation is performed by the nerves (*b*), and indeed the other senses, performed by nerves, are a kind of feeling; so is this sense of feeling performed by

(*a*) Malpighi is of this opinion, that as taste is performed by the papillae in the tongue, so is feeling by such like papillae under the skin. From several dissections, and other observations, he thus concludes, 'Ex his et similibus videbatur animus abunde certior redditus, earundem papillarum pyramidalium copiam, quas alias in lingua descripsi, in locis praecipue exquisitiori tactui dicatis reperiri, eodem progigni nervoso et cuticulari corpore, simulque circumvolvi reticulari involucro, et extimam cuticulam, veluti ultimum terminum attingere.—Microscopio quilibet in manus dorso pro sudore orificia quaedam miro ordine dispersa intueri potest, circa quae frequentia quaedam capitula assurgunt; haec vero sunt papillarum fines, dum a cute assurgentes interpositum superant rete, simulque extimam cuticulam. Haec repetitis sectionibus deprehendi; ex quibus non improbabilius deducam, sicuti ex elatioribus—papillis—in lingua, gustus organon elicitur.—ita ex copiosa harum papillarum congerie—in organis, ubi maxime animalia tactus motione afficiuntur,—adaequatum tactus organum sufficienter haberi.' Malpig. de ext. Tact. Org. p. 26. Consul. quoq; ejusd. Vit. p. 28.

These observations of Malpighi, our late curious and diligent Mr Cowper hath confirmed, and given us very elegant cuts both of the skin, and the papillae, and the nerves, glands, etc. under it, from microscopical observations. Vide Cowper's Anat. Introduct. and Tab. 4.

(*b*) Although the eye be the usual judge of colours, yet some have been able to distinguish them by their feeling. 'Quidam fuit qui venit ad M. Duc. Hetruriae aulam, qui colores per tactum cognoscebat. Pro experimento velum sericum, uniformiter textum, et pluribus coloribus tinctum, offerebatur, et veraciter de colore in singulis partibus judicabat.' Grimald de Lum. et Col. prop. 43. sect. 59.

nerves likewise, spread in the most incomparable, curious manner, throughout the whole body. But to describe their origin in the brain, and spinal marrow, their ramifications to all the parts; their inosculations with one another; and other matters; whereby not only the sense of feeling is performed, but also animal motion, and admirable consent and harmony of all the parts of the body is effected, (to describe, I say, these things), would take up too much time, and I have already, and shall, as I go along, give some hints thereof.

The other thing I shall take notice of, is, the dispersion of this sense throughout the body, both without and within. The other senses, I have observed, are seated in the very best place for the relief and comfort, the guard and benefit of the animal. And forasmuch as it is necessary to the being, and well-being of the body, that every part should be sensible of things safe, or things prejudicial to itself; therefore it is an admirable contrivance of the great Creator, to disperse this sense of feeling throughout every part (c); to distinguish between pleasure and pain; things salutary, and things hurtful to the body.

Thus in the five senses of animals, we have an oeconomy worthy of the Creator, and manifestly demonstrating his power, wisdom, and indulgence. For whether we consider the mechanism of the organs, or the great use and convenience of each sense, we find it noble and grand, curious and artificial; and every way worthy of its infinite Maker, and beyond the wit and power of any thing but a God:

(c) *'Tactus autem toto corpore aequabiliter fusus est, ut omnes ictus, omnesque nimios et frigoris et caloris appulsus, sentire possimus.'* Cic. ubi supra.

'Tactus sensus omnibus est, etiam quibus nullus alius; nam et ostréis, et terrestribus vermibus quoque. Existimaverim omnibus sensum et gustatum esse. Cur enim alios alia saporés appetant? in quo vel praecipua naturae architectio.' Plin. Nat. Hist. l. 10. c. 71.

and therefore we must even deny our senses, by denying them to be God's handy-work.

And now from those chief machines of animal performances and enjoyments, the five senses; let us pass to another thing in common to all the sensitive creatures, which is respiration.

CH A P. VII.

OF RESPIRATION.

OF all the acts of animal life, this is one of the chief, and most necessary. For whatsoever hath animal life, hath also the faculty of respiration, or somewhat equivalent thereto (a). Indeed so con-

(a) The uses assigned to respiration by all the anatomists before Malpighi's discoveries of the structure of the lungs, are so various, and many of them so improbable, that it would be frivolous to recount them. But the more eminent modern anatomists assign these uses: Willis thus sums up his opinion, 'Præcipua pulmonum functio, et usus sunt, sanguinem et aerem per totas partium compages, intimosque recessus, atque ductus quosque minutissimos traducere, et ubique invicem committere; in eum nempe finem, ut sanguis venosus a circuitu redux, et chymus recenti dilutus—tum perfectius misceatur, et velut subigatur, tum potissimum et secundum omnes suas partes ab aere nitroso de novo accendatur.' Pharm. p. 2. sect. 1. c. 2. f. 3. Mayow saith rightly, that one grand use of expiration is, 'Ut cum aere expulso, etiam vapores e sanguine exhalantes, simul exsufflentur.' And as for inspiration, that it conveyeth a nitro-aerial ferment to the blood, to which the animal spirits are owing, and all muscular motion. Mayow de Res. p. 22. etc. mea ed.

Somewhat of the opinion of these two last cited, if I mistake not, (it being long since I read their tracts, and have them not now at my hand), were Ent, Sylvius, Swammerdam, Diemerbroek, and my friend Mr Ray, in an unpublished tract of his, and his letters now in my hands.

But our Dr Thurston, for good reasons, rejects these from being principal uses of respiration, and thinks, with great reason, the principal uses to be, to move, or pass the blood from the right to the left ventricle of the heart. Upon which account persons hanged, drowned, or strangled by catarrhs, so suddenly die, namely, because the circulation of their blood is stopped. For the same reason also it is, that animals die so soon in the air

genial is this with life, that breath and life are in scripture-phrafe and common speech taken as synonymous things, or at least, necessary concomitants

pump. Among other proofs he instanceth in an experiment of Dr Croon, Profesi. Gresh. which he made before our R. S. by strangling a pullet, so that not the least sign of life appeared; but by blowing wind into the lungs through the trachea, and so setting the lungs a playing, he brought the bird to life again. Another experiment was once tried by Dr Walter Needham, before Mr Boyle, and others at Oxford, by hanging a dog, so that the heart ceased moving. But hastily opening the dog, and blowing wind into the ductus Pecquetianus, he put the blood in motion, and by that means the heart, and so recovered the dog to life again. Vide Thurston de Res. Uf. p. 60. and 63. mea ed.

Such an experiment as Dr Croon's, my friend, the late justly renowned Dr Hook, shewed also our Royal Society. He cut away the ribs, diaphragm, and pericardium, of a dog; also the top of the wind-pipe, that he might tie it on to the nose of a pair of bellows; and by blowing into the lungs, he restored the dog to life; and then ceasing blowing, the dog would soon fall into dying fits; but by blowing again, he recovered; and so alternately would die, and recover, for a considerable time, as long and often as they pleased. Phil. Transf No. 28.

For the farther confirmation of Dr Thurston's opinion, the ingenious Dr Musgrave cut off, and close stopped up the wind-pipe of a dog with a cork, and then threw open the thorax; where he found the blood stagnating in the lungs, the arteria pulmonaris, the right ventricle and auricle of the heart, and the two great trunks of the cava, distended with blood to an immense degree; but at the same time, the vena pulmonaris, the left ventricle and auricle of the heart in a manner empty, hardly a spoonful of blood therein. Phil. Transf. No. 240. Or both the experiments may be together met with in Lowth. Abrig. vol. 3. p. 66. 67.

This opinion of our learned Thurston, the late learned Et-mullerus espoused, who being particular in reckoning up the uses of respiration, I shall therefore the more largely cite him. Respiration, saith he, serves, 1. Ad olfactum. 2. Ad sreatum et sputationem. 3. Ad oscitationem, tussim, sternutationem, emunitionemque. 4. Ad liquidorum sorbitionem, suctionemve. 5. Ad loquelam, cantum, clamorem, risum, sletum, flatum, etc. 6. Ad foecum alvi, urinae, foetus molaeve, necnon secundinarum expulsionem. 7. Ad promovenda ventriculi, intestinorum, lacteorumque vasorum, etc. contenta. 8. Ad halitus aqueos sanguinis e pulmonibus, aeris ope, exportandos. 9. Ad diapnoen. 10. Ad exactiorem chyli, lymphaeque, necnon sanguinis—miscelam. 11. Ad conciliandum sanguini—coccineam rubedinem, etc. 12. Nec morose negabimus aerem—pulmones et sanguinem illos transcurrentem, minus calida reddere, etc.

of one another. Moses (*b*) expresseth animal life, by

‘ 13. Quod denique aer sanguini singulis respirationibus aliquantilla sui parte, admixtus, paucissimas quasdam in spirituum animalium elaboratione particulas simul contribuat.’ All these uses, although of great consequence, yet he thinks rather conduce to the well-being, than the being of the animal; because without any of them, the animal would not so speedily die, as it doth by strangling, or in the air-pump. He therefore assigns a 14th, and the principal use of respiration to be, ‘For the passing of the blood through the lungs, that is thrown into them by the heart.’ Etmul. Dissert. 2. cap. 10. sect. 1. et 16.

But the late Dr Drake, with great ingenuity and address, (like a person so considerable for his years, as he was in his time), not only established this motion of respiration, but also carries it farther, making it the true cause of the diastole of the heart; which neither Borelli, Lower, or Cowper, much less any before those great men, have well accounted for. That the heart is a muscle, is made evident beyond all doubt by Dr Lower. And that the motion of all muscles consists in constriction, is not to be doubted also. By which means the systole is easily accounted for. But forasmuch as the heart hath no antagonist-muscle, the diastole hath puzzled the greatest wits. But Dr Drake, with great judgment, and much probability of reason, maketh the weight of the incumbent atmosphere to be the true antagonist to all the muscles, which serve both for ordinary inspiration, and the constriction of the heart. The particulars of his opinion may be seen in his anatomy, l. 2. c. 7. and in Phil. Trans. No. 281.

And I remember when I was at the university, my most ingenious and learned tutor Dr Willis, when he read anatomy to us, was of opinion, that the lungs were blown up by the weight of the incumbent air, and represented the manner of respiration in this manner, viz. he put a bladder into a pair of bellows, turning back the neck of the bladder, and tying it fast, so that no air might enter in between the bladder and bellows. This being done, when the bellows were opened, the bladder would be blown up by the weight of the incumbent air; and when shut, the air would be thereby pressed forcibly out of the bladder, so as to blow the fire. This experiment I take notice of here, because (besides the illustration it gives to respiration) that great genius seems to have had a truer notion of this phenomenon, than was very common then, viz. about the year 1677, or 78; as also, because I have, in some authors, met with the same experiment, without mention of Dr Willis, whose I take it to have been.

Another use of great consideration, the already commended Dr Cheyne assigns; namely, to form the elastic globules of which the blood principally consists, without which there would be a general obstruction in all the capillary arteries. Cheyne's Philos. Princ. of Nat. Relig. or Harris's Lex. Tech. in Lungs.

(*b*) Gen. ii. 7. vi. 17. and vii. 15.

‘ the breath of life.’ Saith he, Gen. vii. 21. 22.
 ‘ All flesh that moveth on the earth, fowl, cattle,
 ‘ beast, creeping things, and man ; all in whose
 ‘ nostrils was the breath of life in the dry land died.’
 So the psalmist, Psal. civ. 29. ‘ Thou takest away
 ‘ their breath, they die.’ So grand an act therefore
 in common to all animals, may justly deserve a place
 in this survey of the works of God in the animal
 kingdom.

And here I might launch out into an ample description of all the parts ministering to this necessary act, and shew the curious contrivance, and artificial structure of them ; but a transient view shall suffice. I might begin with the outward guards, the nose and mouth ; but these have been already touched upon. But the exquisite mechanism of the larynx, its variety of muscles, its cartilages, all so exquisitely made for the purpose of respiration, and forming the voice (c),

(c) Because it would be endless to specify the curious mechanism of all the parts, concurring to the formation of the voice ; I shall therefore for a sample note only two things : 1. There are thirteen muscles provided for the motion of the five cartilages of the larynx. Gibb. Anat. l. 2. c. 14. A sign of the careful and elaborate provision that is made for the voice. 2. It is a prodigious faculty of the glottis, in contracting and dilating itself with such exquisiteness, as to form all notes. ‘ For, (as the late ingenious Dr Keil saith), supposing the greatest distance of the two sides of the glottis, to be one tenth part of an inch in sounding twelve notes, to which the voice easily reaches ; this line must be divided into twelve parts, each of which gives the aperture requisite for such a note, with a certain strength. But if we consider the sub-division of notes, into which the voice can run, the motion of the sides of the glottis is still vastly nicer. For if two chords sounding exactly unisons, one be shortened one two thousandth part of its length, a just ear will perceive the disagreement, and a good voice will sound the difference ; which is one hundred and ninety sixth part of a note. But suppose the voice can divide a note into a hundred parts, it follows, that the different apertures of the glottis actually divide the tenth part of an inch into twelve hundred parts, the effect of each of which produces a sensible alteration upon a good ear. But because each side of the glottis moves just equally, therefore the divisions are just doubled ; or the sides of the glottis, by their motion, do actually divide one tenth

are very admirable: and no less so is the tongue (*d*), which ministers to that, and many other uses too.

Next, the fabric of the (*e*) trachea deserves especial remark. Its valve, the epiglottis on the top, to fence against all annoyances; its cartilaginous rings (*f*) nearly environing it, with its membranous part next

'part of an inch into two thousand four hundred parts.' Keil's Anat. cap. 3. sect. 7.

(*d*) Among the instruments of speech, the tongue is a necessary one; and so necessary, that it is generally thought no speech can be without it. But in the third tome of the *Ephem. Germ.* is published, '*Jac. Rolandi Aglossostomographia, sive Descriptio Oris sine Lingua quod perfecte loquitur, et reliquas suas functiones naturaliter exercet.*' The person described is one Pet. Durand, a French boy of eight or nine years old, who, at five or six, lost his tongue by a gangrene, occasioned by the small pox: notwithstanding which, he could, as the title saith, speak perfectly, as also taste, spit, swallow, and chew his food; but this latter he could do only on that side he put it into, not being able to turn it to the other side of his mouth.

In the same tract, chap. 6. is this observation of Ventriloquous persons; '*Memini me a quodam sat celebri anatomico audivisse, dum de duplicatura mediastini ageret, si membrana ista duplex naturaliter unita in duas partes dividatur, loquelam quasi ex pectore procedere, ut circumstantes credant Daemoniacum hunc, aut Sternomythum.*'

(*e*) 'The variation of the wind-pipe is observable in every creature, according as it is necessary for that of the voice. In an urchin, which hath a very small voice, it is hardly more than membranous: and in a pidgeon, which hath a low and soft note, it is partly cartilaginous, and partly membranous. In an owl, which hath a good audible note, it is more cartilaginous; but that of a jay hath hard bones instead of cartilages; and so of a linnet: whereby they have both of them a louder and stronger note,' etc.

'The rings of the wind-pipe are fitted for the modulation of the voice: for in dogs and cats, which in the expression of divers passions use a great many notes, as men do, they are open and flexible, as in man. Whereby all, or any of them, are dilated or contracted, more or less, as is convenient for a higher or deeper note, etc.; whereas in some other animals, as in the Japan-peacock, which useth hardly more than one single note, they are entire,' etc. Grew's *Cosmol. Sacr.* book i. chap. 9. sect. 9, 10.

(*f*) It is a further manifest indication of singular design in the cartilaginous rings of the *aspera arteria*, that all the way where they are contiguous to the oesophagus, they are membranous, to afford an easy passage to the food; but after that, in the bron-

the gullet, to give the freer passage to the descent of the food: and lastly, its inner tegument, of exquisite sense, to be readily affected with, and to make efforts against every thing that is hurtful or offensive; these, I say, do all justly deserve our admiration.

And no less prodigious are the parts farther within; the bronchi, the vesiculæ (*g*), with their muscular fibres (*h*), as some assert they have, together with the arteries and veins, which every where accompany the airy passages, for the blood to receive there its impregnations from the air.

From hence I might proceed to the commodious

chi, they are, some completely angular, some triangular, etc. And another observable is, the lower parts of the superior cartilages, receive the upper parts of the inferior in the bronchi; whereas in the aspera arteria, the cartilages run and remain parallel to one another, which is a noble difference or mechanism in this, in a manner, one and the same part, enabling the lungs, and bronchi, to contract themselves in expiration, and to extend and dilate themselves in inspiration.

(*g*) I shall not here intrench so much upon the anatomist's province, to give a description of the lungs, although it be a curious piece of God's workmanship; but refer to signior Malpighi, the first discoverer of their vesiculæ in 1660, in his two letters to Borelli de Pulmon. Also to Dr Willis's Pharm. rat. p. 2. sect. 1. c. 1. de Resp. Orig. et Uf. who, as he wrote after Malpighi, hath more accurately described those parts; and to Mr Cowper's Anat. tab. 24, 25. And if the reader hath a mind to see what opposition signior Malpighi's discoveries met with at home and abroad, and what controversies he had on that account; as also his censures of Dr Willis's description and figures, he may consult Malpighi's life, written by himself, p. 4. to 21.

That the lungs consist of vesiculæ, or lobuli of vesiculæ admitting of air from the bronchi, is visible, because they may be blown up, cleansed of blood, and so dried. But Mr Cowper saith, he could never part the lobuli, (so as to make Dr Willis's fig. 1. tab. 3. and 4.) so that probably the vesiculæ are contiguous to one another throughout each lobe of the lungs. And not only air, but Diemerbroeck proves, that the vesiculæ admit of dust also, from two asthmatic persons he opened; one a stone-cutter's man, the vesiculæ of whose lungs were so stuffed with dust, that in cutting, his knife went as if through a heap of sand: the other was a feather-driver, who had these bladders filled with the fine dust or down of feathers.

(*h*) There is a considerable difference between Dr Willis and Etmuller, viz. whether the vesiculæ of the lungs have any mus-

form of the ribs (*i*), the curious mechanism of the intercostal muscles (*k*), the diaphragm, and all the

cular fibres, or not? Etmüller expressly saith, 'Nullas fibras musculosas, multo minus rubicundam musculorum compagem (sunt enim vesiculæ albidae et fere diaphanae) in ipsis reperiri.' Ubi sup. c. 6. sect. 2. And afterwards, sect. 3. 'Pulmones esse molles flexilesque musculosas fibris ceu propriae explicationis organis destitutos.' But Dr Willis as expressly asserts, they have muscular fibres, and assigns an excellent use of them; 'Cellulae istae vesiculares, ut nixus pro expiratione contrahere edant, etiam fibras, uti per microscopium plane conspiciere est, musculares obtinent.' Ubi sup. sect. 16. And in the next section, 'Ut pro data occasione majorem aeris copiam exsufflent, aut materiam excretiendam ejiciant, fibris muscularibus donatae, sese arctius contrahunt, contentaque sua penitus exterminant. Et enim ordinariae pectoris systolae, quas musculorum relaxationes ex parte efficiunt, aerem forsan totum a trachea et bronchis, haud tamen a vesiculis, quaque vice ejiciunt; propter has, quoties opus erit, inaniendas, et totius pectoris cavitas plurimum angustatur, et cellulae ipsae vesiculares a propriis fibris confistrictis coarctantur.'

(*i*) 'Circa hos motus [scilicet] pectoris dilatationem, etc.' divini conditoris mechanice, ad regulas mathematicas plane adaptata, fatis admirari non possumus: siquidem nulla alia in re manifestius, 'Ο Θεός γινώσκων videtur. Quippe cum pectoris, tum ampliatio, tum coarctatio a quibusdam musculis (quorum munus unicum est contrahere) perfici debeat; res ita instituitur, ut costae quae thoracis, velut parallelogramma oblongi versus cylindrum incurvati, latera efformant, in figuram modo quadratam, cum angulis rectis, pro pectoris ampliatione; modo in rhomboidem, cum angulis acutis pro ejusdem contractione, ducantur,' etc. Willis, ubi supra, sect. 28.

Galen having spoken of the parts ministering to respiration, concludeth, 'Nihil usquam a natura illo pacto per incuriam, fuisse praeteritum, quae cum omnia praesentiret et provideret, quae sunt necessaria illa, quae causa alicujus extiterunt, consuetudine omnibus instaurationes parare occupavit, cujus apparatus copiosa facultas admirabilem sapientiam testatur.' De Usu Part. l. 5. c. 15. See also l. 6. c. 3.

(*k*) For the structure of the intercostals, midriff, etc. I shall refer to Dr Willis, and other anatomists. But Dr Drake taxeth Dr Willis with an error, in fancying there is an opposition in the office of the intercostals, by reason that the fibres of the external and internal intercostals decussate; that therefore the external serve to raise the ribs, the internal to draw them down. But Dr Drake is of Steno's, and Dr Mayow's opinion, that notwithstanding the decussation of their fibres, the power they exert upon, and the motion they effect in the ribs, is one and the same. Drake's Anat. l. 2. c. 7. and l. 4. c. 5. Mayow de Respir. c. 7.

other muscles (*l*), ministering both to the ordinary, and extraordinary offices of respiration. But passing them by, I shall stop at one prodigious work of nature, and manifest contrivance of the almighty Creator, which, although taken notice of by others (*m*), yet cannot be easily passed by in the subject I am upon; and that is, the circulation of the blood in the foetus in the womb, so different from the method thereof after it is born. In the womb, whilst it is one body with the mother, and there is no occasion, nor place for respiration, there are two passages (*n*)

(*l*) Although Dr Drake, and some others, deny the intercostals being antagonist muscles, as in the preceding note; yet they, and most other anatomists that I have met with, attribute a considerable power to them in the act of respiration, as they do also to the subclavian and triangular muscles; but the learned Etmüller denies it for these three reasons. 1. 'Quia respirando nullam in illis contractionem sentio. 2. Quia—sibi invicem non adducuntur, etc. 3. Quia costae omnes ab aliis modo enarratis musculis moventur, idque simul, etc. Intercostales itaque, nec non subclavios musculos costis, parietum instar, ad complenda interstitia intercostalia, pectusque integrandum, ac costas connectendas, interjectos esse, probabiliter concludo; quo munere triangulares etiam—fungi, rationi consentaneum est.' Etmüller. *libert. 2. c. 4. sect. 6.*

But as to the use of the triangular muscle in respiration, we may judge of it, from its remarkable size and use in a dog; of which Dr Willis gives this account from Fallopius: 'In homine parvus adeo et subtilis iste [musculus] est, ut vix pro musculo accipi queat: in cane per totum os pectoris protenditur, et cartilagine omnes, etiam verarum costarum sterno inosculatas, occupat: cujus discriminis ratio divinam circa animalium fabricas providentiam plane indigitat. Quippe cum hoc animal, ad cursus velocissimos et diu continuandos natum, quo sanguis, dum intensius agitur, rite accendatur eventileturque, aerem celerrime et fortiter uti superare, ita etiam expirare debet—idcirco propter hunc actum firmitus obnoxium (cujus in homine haud magnus est usus) musculus caninus molem inwentem et tanto operi parem fortitur.' Willis ubi supra, p. 32.

(*m*) Ray's Wisdom of God in the Creation, p. 343.

(*n*) Mr Cheselden, an ingenious and most accurate anatomist, being somewhat particular in his observations about the circulation of the blood through the heart of the foetus, I shall present the reader with some of his observations, which he favoured me with the sight of. 'The blood, saith he, which is brought to the

on purpose for the transmission of the blood, without passing it through the lungs. But as soon as the foetus is born, and becomes thereby a perfectly distinct being, and breathes for itself, then these two passages are shut up; one nearly obliterated, the other becomes only a ligament, except in some creatures that are amphibious, or are forced to lie long under water, in whom these passages probably remain open (c).

* heart by the ascending cava, passes out of the right auricle into
 * the left, through a passage called foramen ovale, in the septum
 * [common to them both], without passing through the right ven-
 * tricle, as after the birth, while the blood from the descending
 * cava passeth through the right auricle and ventricle into the
 * pulmonary artery, and thence into the aorta through the duct
 * betwixt that and the pulmonary artery, called ductus arteriosus,
 * whilst a small portion of the blood, thrown into the pulmonary
 * artery, passeth through the lungs, no more than is sufficient to
 * keep open the pulmonary vessels. Thus both ventricles are
 * employed in driving the blood through the aorta to all parts of
 * the foetus, and to the mother too. But after the birth, the
 * blood being to be driven from the aorta through the foetus a-
 * lone, and not the mother too, one ventricle becomes sufficient,
 * whilst the other is employed in driving the blood through the
 * lungs, the ductus arteriosus being shut up by means of the al-
 * teration of its position, which happens to it from the raising of
 * the aorta by the lungs, when they become inflated. After that
 * the blood is thus driven into the lungs, in its return it shuts
 * the valve of the foramen ovale against the foramen itself, to
 * whose sides it soon adheres, and so stops up the passage. The
 * ductus arteriosus, or ductus arteriosus in ligamentum verus,
 * is seldom to be discerned but in adult bodies, but the figure of
 * the foramen ovale is never obliterated.

(c) It hath been generally thought to be not improbable, but
 that on some occasions the foramen ovale may remain open in
 man. In a girl of four or five years of age, Dr Conner found it
 but half closed, and in the form of a crescent. And he thinks
 somewhat in this kind might be in the person whose skeleton was
 found to have no joints in the back-bone, ribs, etc. Of which
 description, with cuts, may be found in Phil. Trans. No. 213.
 And more largely in his Diff. Med. Phys. de stupendo Ossium
 coalitu, where he adds to the girl, in whom the foramen ovale
 was not shut, a like observation of another girl he opened at Ox-
 ford of three years old; 'In qua foramen ovale fere erat occlu-
 sum, in medio tamen, exili foramine, per quod turundam
 cile transiit, erat pervium,' p. 30. So Mr Cowper (than whom
 none more accurate and better judge) saith, 'I have often found
 the foramen ovale open in the adult.' Anat. Appen. fig.

And now what action of any rational creature, what is there in a man's life, that doth more plainly shew design, reason, and contrivance, than this very act of nature doth the contrivance and design of the great God of nature? What is thought and contrivance, if this be not? namely, that there should be a temporary part in the body, made just for the present exigence; to continue whilst there is occasion for it, and to cease when there is none; in some creatures to remain always, by reason of their amphibious way of living, and in land animals, purely such, to cease.

Another excellent contrivance, akin to the last, is, for the preservation of such creatures whose occasions frequently necessitate them to live without, or,

But Mr Cheselden is of a different opinion, of which in the following note.

From somewhat of this cause, I am apt to think it was that the Tronningholm gardiner escaped drowning, and some others mentioned by Pechlin. His stories are, 'Hortulanus Tronningholmenfis etiamnum vivens, annos natus 65, pro illa aetate satis adhuc valens, et vegetus, cum ante 18 annos, alii in aquas delapso opem ferre vellet, forte fortuna et ipse per glaciem incautius procedens, aquas incidit 18 ulnas profundas: ubi ille, corpore erecto quasi ad perpendicularum, pedibus fundo adhaesit. Constitit sic per 16 horas, antequam produceretur in auras. Dixit autem simul ac infra aquarum superficiem fuit demersus, statim obriguisset totum, et, si quem tum habuit motum et sensum, amisisset, nisi quod sonantes Stockholmii campanas etiam sub aquis obscurius percipere sibi sit visus. Sensit etiam, statim sese velut vesiculam ori applicasse, adeo ut aqua nulla os penetraverit, in aures vero transitum, etiam sentiente illo, habuerit; atque inde auditum suum debilitatum aliquandiu esse. Hoc statum 16 horas permansit frustra quaesitus, tandem repertum, conto in caput infixum, cujus etiam sensum se habuisse dixit, fundo extraxerunt, sperantes ex more aut persuasione gentis revivisciturum esse. Itaque pannis linteisque productum obvolvunt, ne aer admitti possit perniciosus futurus subito illapsu: custoditum sic satis ab aere sensim sensimque tepidiori loco admovent, mox calidis adiunguntur, fasciis, fricant, radunt, et sufflaminatum tot horis sanguinis corporisque motum negotiosa illa opera reducunt: denique antapoplecticis et genialibus liquoribus vitae reddunt et pristinae mobilitati. Retulit is atque ostendit se etiamnum in capite circumferre vestigia violentiae a conto illatae et cephalagiis vexari gravissimis. Et propter hunc ipsum casum, religiose a popularibus, et huiusce rei testibus probatum,

with but little respiration: fishes might be named here, whose habitation is always in the waters; but these belong to an element which I cannot at present engage in. But there are many animals of our own element, or partly so, whose organs of respiration, whose blood, whose heart, and other instruments of life are admirably accommodated to their method of living: thus many amphibious creatures (*p*) who live

• *serenissimae reginae matris munificentia et annuo stipendio est*
 • *donatus—et serenif. Principi—oblatus vivus sui testis—*
 • *Consignatum manu habes historiam D. Tilasii, Biblioth. Reg.*
 • *Praefecti, qui testatus est se praenovisse mulierem, quae tres*
 • *ipfos dies sub aquis haesit, et similem in modum, quo Hortu-*
 • *lanus ille, resuscitata, adhuc dum lucis plena fruitur usura.*
 • *Accedit Nob. Burmanni—fides, qui confessus est,—se in pago*
 • *Boness parochiae Pithoviae concionem frequentasse funebrem,*
 • *in qua, dum acta recenseret praeco senis cujusdam septuagenarii*
 • *Lau. Jonae—audiverit ex ore concionatoris, vivum eum,*
 • *adolefcentem 17 annorum, aquis submersum, 7 demum heb-*
 • *domada (rem prodigiosam!) extractum ad se rediisse vivum et*
 • *incolumem.* Pechlin. de Aer. et Alim. def. c. 10.

Shall we to this cause, or to the ossification, or more than ordinary strength of the wind-pipe, attribute the recovery to life of persons hanged? Of which Pechlin gives an instance that fell under his own knowledge, of a woman hanged, and in all appearance dead, but recovered by a physician accidentally coming in, with a plentiful administration of Spir. Sal. Armon. Pechl. *ibid.* c. 7. And the story of Anne Green, executed at Oxford, Dec. 24, 1650, is still well remembered among the seniors there. 'She was hanged by the neck near half an hour, some of her friends in the mean time thumping her on the breast, others hanging with all their weight upon her legs, sometimes lifting her up, and then pulling her down again with a sudden jirk, thereby the sooner to dispatch her out of her pain;' as her printed account wordeth it. After she was in her coffin, being observed to breathe, a lusty fellow stamped with all his force, on her breast and stomach, to put her out of her pain. But by the assistance of Dr Piety, Dr Willis, Dr Bathurst, and Dr Clarke, she was again brought to life. I myself saw her many years after, after that she had, I heard, born divers children. The particulars of her crime, execution, and restauration, see in a little pamphlet called, *News from the Dead*, written, as I have been informed by Dr Bathurst, (afterwards the most vigilant and learned president of Trinity-College, Oxon), and published in 1651, with verses upon the occasion.

(*p*) The sea-calf hath the foramen ovale, by which means it

in water as well as air; many quadrupeds, birds, insects, and other animals, who can live some hours, days, yea, whole winters, with little or no respiration, in a torpitude, or sort of sleep, or middle state between life and death: the provision made for these peculiar occasions of life, in the fabric of the lungs, the heart, and other parts of such creatures (*g*), is manifestly the work of him who, as St Paul saith (*r*), 'giveth to all breath and life, and 'all things.'

C H A P. VIII.

Of the Motion of Animals.

NEXT to the two grand acts of animal life, their sense and respiration, I shall consider their motion, or locomotive faculty, whereby they

enabled to stay long under the water, as the Paris Anatomists. Of which see in book vi. chap. 5. note (*b*).

But the fore-commended Mr Cheselden, thinks the foramen ovale is neither open in amphibious creatures, nor any adult land-animals. 'When I first, saith he, applied myself to the dissection of human bodies, I had no distrust of the frequent accounts of the foramen ovale being open in adults; but I find since, that I mistook the ostium venarum coronarium for the foramen. The like I suppose authors have done, who assert that it is always open in amphibious animals; for we have made diligent inquiry into those animals, and never found it open. Neither would that, as they imagine, serve these creatures to live under water, as the foetus doth in utero, unless the ductus arteriosus was open also.'

This opinion of Mr Cheselden hath this to render it probable, that the ostium venarum coronarium is so near the foramen ovale, that without due regard, it may be easily mistaken for it. Such therefore as have opportunity of examining this part in amphibious animals, or any other subject, ought to seek for the ostium, whenever they suspect they have met with the foramen.

(*g*) Of the singular conformation of the heart and lungs of the tortoise, which is an amphibious animal, see book vi. chap. 5. note (*b*).

(*r*) Acts xvii. 25.

convey themselves from place to place, according to their occasions and way of life: and the admirable apparatus to this purpose is a plain demonstration of God's particular foresight, care and especial providence towards all the animal world.

And here I might view, in the first place, the muscles, their curious structure (a), the nice tacking them to every joint, to pull it this way, and that way, and the other way, according to the special purpose, design and office of every such joint: also their various size and strength; some large and corpulent, others less; and some scarce visible to the naked eye; all exactly fitted to every place, and every use of the body. And lastly, I might take notice of the muscular motions, both involuntary and spontaneous (b).

(a) That the muscles are compounded of fibres, is visible enough. Which fibres, the curious and ingenious Borelli saith, are cylindraceous; not hollow, but filled with a spongy, pithy substance, after the manner of elder, as he discovered by his microscopes. Borel. de Mot. Animal. Part 1.

These fibres, he saith, are naturally white; but derive their redness only from the blood in them.

These fibres do in every muscle (in the belly at least of the muscle) run parallel to one another, in a neat orderly form. But they do not all tend the same way, but some run aslant, some long ways, etc. according to the action or position of each respective muscle. The particulars of which, and of divers other observables in the muscles, would, besides figures, take up too much room in these notes; and therefore I must refer to the anatomists, particularly Steno, Borelli, Cowper, etc.

(b) The infinite Creator hath generally exerted his art and care, in the provision made by proper muscles and nerves, for all the different motions in animal bodies, both involuntary, and voluntary. It is a noble providence, that most of the vital motions, such as the heart, stomach, guts, etc. are involuntary, the muscles acting whether we sleep or wake, whether we will or no. And it is no less providential that some, even of the vital motions, are partly voluntary, partly involuntary, as that, for instance, of breathing, which is performed both sleeping and waking; but can be intermitted for a short time on occasion, as for accurate hearing any thing, etc. or can be increased by a stronger blast, to make the greater discharges of the blood from the lungs, when that any thing overcharges them. And as for the other motions of the body, as of the limbs, and such as are voluntary, it is no less providence that they are absolutely under the power of the

Next I might survey the special fabric of the bones (c), ministering to animal motion. Next, I

will; so as that the animal hath it in his power to command the muscles and spirits, or any part of its body, to perform such motions and actions as it hath occasion for.

(c) ' Quid dicam de ossibus? quae subjecta corpori mirabiles commissuras habent, et ad stabilitatem aptas, et ad artus finiendo accommodatas, et ad motum, et ad omnem corporis actionem.' Cicer. de Nat. Deor. l. 2. c. 55.

By reason it would be endless to mention all the curiosities observable in the bones, I shall, for a sample, single out only an instance or two, to manifest that design was used in the structure of these parts in man.

The first shall be in the back-bone, which among many others, hath these two things remarkable. 1. Its different articulations from the other joints of the body. For here most of the joints are flat, and withal guarded with asperities and hollows, made for catching and holding; so as firmly to lock and keep the joints from luxations, but withal to afford them such a motion, as is necessary for the incurvations of the body. 2. The difference of its own joints in the neck, back, and loins. In the neck, the atlas, or upper vertebra, as also the dentata, are curiously made and jointed, differently from the rest, for the commodious and easy bending and turning the head every way. In the thorax, or back, the joints are more close and firm; and in the loins, more lax and pliant; as also the spines are different, and the knobs and sockets turned the quite contrary way, to answer the occasions the body hath to bend more there than higher in the back. I shall close this remark with the late ingenious Dr Keil's observation.

' The structure of the spine is the very best that can be contrived; for had it been all bone, we could have had no motion in our backs; had it been of two or three bones articulated for motion, the medulla spinalis must have been necessarily bruised at every angle or joint; besides, the whole would not have been so pliable, for the several postures we have occasion to put ourselves in. If it had been made of several bones without intervening cartilages, we should have had no more use of it, than if it had but one bone. If each vertebra had had its own distinct cartilages, it might have been easily dislocated. And lastly, the oblique processes of each superior and inferior vertebra keep the middle one, that it can neither be thrust backwards nor forwards to compress the medulla spinalis.' Keil's Anat. cap. 5. sect. 8.

Compare here what Galen saith of the articulations, ligaments, perforation, etc. of the spine, to prove the wisdom and providence of the Maker of animal bodies, against such as found fault with nature's works; among which he names Diagoras, Anaxagoras, Asclepiades, and Epicurus. Vide Galen de Usu Part. l. 12. init. and cap. 15, etc. also l. 13. init.

might take notice of the joints (*d*), their complete form-adjusted to the place, and office they are employed in; their bandage keeping them from luxations; the oily matter (*e*) to lubricate them, and their own smoothness to facilitate their motion.

2. The next instance shall be in one or two things, wherein the skeletons of sexes differ. Thus the pelvis made in the belly by the ilium, ossa coxendicis, and pubis, is larger in a female than male skeleton, that there may be more room for lying of the viscera and foetus. So the cartilage bracing together the two ossa pubis, or sharebones, Bortholine saith, is twice thicker and laxer in women than men: as also is the cartilage that tieth the os sacrum to its vertebra; and all to give way to the passage of the foetus.

Another considerable difference is in the cartilaginous production of the seven long ribs, whereby they are braced to the breast-bone. These are harder and firmer in women than in men; the better to support the weight of the breasts, the sucking infant, etc.

(*d*) It is remarkable in the joints, and a manifest act of caution and design: 1. That although the motion of the limbs be circular, yet the center of that motion is not in a point, but an ample superficies. In a point, the bones would wear and penetrate one another; the joints would be exceedingly weak, etc. but the joints consisting of two large superficies, concave, and convex, some furrowed and ridged, some like a ball and socket, and all lubricated with an oily substance, they are incomparably prepared both for motion and strength. 2. That the bones next the joint are not spungy, as their extremities commonly are, nor hard and brittle, but capped with a strong, tough, smooth, cartilaginous substance, serving both to strength and motion.

But let us here take notice of what Galen mentions on this subject. *Articulorum unusquisque eminentiam cavitati immissam habet: veruntamen hoc fortasse non adeo mirabile est: sed si considerata omnium totius corporis ossium mutua connexione, eminentias cavitatibus suscipientibus aequales semper inveniatis, hoc mirabile. Si enim justo amplior esset cavitatis, laxus sane et infirmus fieret articulus; si strictior, motus difficulter fieret, ut qui nullam versionem haberet; ac periculum esset non parvum eminentias ossium arctatas frangi: sed horum neutrum factum est.—Sed quoniam ex tam secura constructione periculum erat, ne motiones difficilius fierent, et eminentiae ossium extenderentur, duplex rursus auxilium in id natura molita est. 1. Cartilagine os utrumque subjungens, atque obtinens: alterum, ipsi cartilaginibus humorum unctuosum, velut oleum, superfundens, per quem facile mobilis et attritu contumax omnis articulationis ossium facta est.—Ut undique diligenter articulus omnis custodiretur, ligamenta quaedam ex utroque osse produxit natura.* Galen de Us. Part. l. i. c. 15.

(*e*) For the affording this oily or mucilaginous matter, there

And lastly, I might trace the various nerves throughout the body, sent about to minister to its various motions (*f*). I might consider their origin (*g*), their ramifications to the several parts, and their inosculations with one another, according to the harmony and accord of one part with another, necessary for the benefit of the animal. But some of these things I have given some touches upon already, and more I shall mention hereafter (*h*), and it would be tedious here to insist upon them all.

I shall therefore only speak distinctly to the locomotive act itself, or what directly relates to it.

And here it is admirable to consider the various methods of nature (*i*), suited to the occasions of va-

are glandules very commodiously placed near the joints, so as not to suffer too great compression by the motion of the neighbouring bones, and yet to receive a due pressure, so as to cause a sufficient emission of the mucilage into the joints. Also, another thing considerable is, that the excretory ducts of the mucilaginous glands have some length in their passage from the glands to their mouths; which is a good contrivance, to prevent their mouths being oppressed by the mucilage, as also to hinder the too plentiful effusion thereof, but yet to afford a due expressure of it at all times, and on all occasions, as particularly in violent and long-continued motions of the joints, when there is a greater than ordinary expence of it. See Cowp. An. tab. 79.

(*f*) There is no doubt to be made, but that the muscles receive their motion from the nerves. For if a nerve be cut or straightly bound, that goes to any muscle, that muscle shall immediately lose its motion. Which is doubtless the case of paralytics; whose nerves are some of them by obstructions, or such like means, reduced to the same state as if cut or bound.

And this also is the cause of that numbness or sleepiness we find oftentimes, by long sitting or lying on any part.

Neither is this a modern notion only; for Galen saith, '*Principium nervorum omnium cerebrum est, et spinalis medulla.*—

Et nervi a cerebro animalem virtutem accipiunt.—*Nervorum utilitas est facultatem sensus et motus a principio in partes deducere.*' And this he intimates to have been the opinion of Hippocrates and Plato, de Uf. Part. l. i. c. 16. et passim.

(*g*) Dr Willis thinks, that in the brain the spirits are elaborated that minister to voluntary motion; but in the cerebellum, such as affect involuntary, or natural motions; such as that of the heart, the lungs, etc. Cerebri. Anat. c. 15.

(*h*) See book v. chap 8.

(*i*) To the foregoing. I shall briefly add some examples of the

rious animals. In some their motion is swift, in others slow; in some performed with two, four, or more legs; in some with two, or four wings; in some with neither (*k*).

And first for swift or slow motions. This we find is proportional to the occasions of each respective animal. Reptiles, whose food, habitation, and nests, lie in the next clod, plant, tree, or hole, or can bear long hunger and hardship, they need neither legs nor wings for their transportation; but their vermicular or sinuous motion (performed with no less art, and as curiously provided for as the legs or wings of other creatures; this, I say) is sufficient for their conveyance.

Man and beasts, whose occasions require a large room, have accordingly a swifter motion, with proper engines for that service; answerable to their range for food, their occupation of business, or their want of armature; and to secure them against harms (*l*).

special provision made for the motion of some animals by temporary parts. Frogs and toads, in their tadpole-state, have tails, which fall off when their legs are grown out. The *lacerta aquatica*, or water newt, when young, hath four neat ramified fins, two on a side, growing out a little above its fore legs, to poise and keep its body upright, (which gives it the resemblance of a young fish), which fall off when the legs are grown. And the *nymphae* and *aureliae*, of all or most of the insects bred in the waters, as they have particular forms, different from the insects they produce, so have also peculiar parts afforded them for their motions in the waters; oars, tails, and every part adapted to the waters, which are utterly varied in the insects themselves, in their mature state in the air.

(*k*) 'Jam vero alia animalia gradiendo, alia serpendo, ad prae-
'stium accedunt, alia volando, alia nando.' Cic. de Natura Deorum.
l. 2. c. 47.

Compare also what Galen excellently observes concerning the number of feet in man, and in other animals; and the wise provision thereby made for the use and benefit of the respective animals. De Usu Part. in the beginning of the third book.

(*l*) As I shall hereafter shew, that the indulgent Creator hath abundantly provided for the safety of animals by their clothing, habitations, sagacity, and instruments of defence; so there appears to be a temperament of their motion with these provi-

But for the winged creatures, birds and insects, as they are to traverse large tracks of land and water, for their food, for their commodious habitation, or breeding their young, to find places of retreat and security from mischiefs; so they have accordingly the faculty of flying in the air; and that swiftly and slowly, a long or short time, according to their occasions and way of life. And accordingly their wings, and whole body, are curiously prepared for such a motion; as I intend to shew in a proper place (*m*).

Another remarkable thing in the motive faculty of all creatures, is the neat, geometrical performance of it. The most accurate mathematician, the most skilful in mechanic motions, cannot prescribe a nicer motion than what they perform, to the legs and wings of those that walk or fly (*n*), or to the bodies of those that creep (*o*). Neither can the body be more completely poised for the motion it is to have in every creature, than it already actually is. From the largest elephant to the smallest mite, — find the body artfully balanced (*p*). The head not too heavy, nor too light for the rest of the body, nor the rest of the body for it (*q*). The viscera are not let loose, or so

ons. They that are well armed and guarded, have commonly slower motion; whereas they that are destitute thereof, are swifter. So also timid helpless animals are commonly swift; as deer and hares: but animals endowed with courage, cast, fangs, etc. commonly have a slower motion.

(*m*) See book vii. chap. 1.

(*n*) See book vii. chap. 1. the end.

(*o*) See book ix. chap. 1. note (*o*).

(*p*) ‘Siquis unquam alius opifex, aequalitatis et proportionis magnam habuit providentiam, certe natura habuit in animalium corporibus conformandis; unde Hi pocrates eam rectissime justam nominat.’ Galen de Usu Part. I. 2. c. 26.

(*q*) The make of the bodies of some water-fowl, seems to contradict what I here say, the heads and long necks of some, as of swans, ducks, and geese; and the hinder parts of others, as of the doucker and moor-hen, and some other kinds, seeming to be too heavy for the rest of their body. But instead of being an argument against, it is a notable instance of the divine art and pro-

placed, as to swag, over-balance, or over-set the body; but well-braced, and distributed to maintain the aequipoise of the body. The motive parts also are admirably well fixed in respect to the centre of gravity; placed in the very point, fittest to support and convey the body. Every leg beareth his true share of the body's weight. And the wings so nicely are set to the centre of gravity, as even in that fluid medium, the air, the body is as truly balanced, as we could have balanced it with the nicest scales.

But among all creatures, none more elegant than the sizing the body of man, the gauging his body so nicely, as to be able to stand erect, to stoop, to sit, and indeed to move any way, only with the help of so small a stay as the feet (*r*); whose mechanism of bories, tendons, and muscles to this purpose, is very curious and admirable.

CH A P. IX.

Of the PLACE allotted to the several tribes of Animals.

HAVING dispatched the motion of animals, let us in the next place consider the place which the infinitely wise Creator hath appointed them to move and act, and perform the offices of the creation in. And here we find every particular well ordered. All parts of our terraqueous globe fit for an animal to live and act in, are sufficiently stocked with proper inhabitants: the watery element (unfit, one

vidence, these things being nice accommodations to their way of life. Of such as have long necks, see book vii. chap. 2. note (*h*).

And as for such whose hinder parts seem to over-balance their foremost parts, whereby they fly with their bodies in a manner erect, this also is an excellent accommodation to their way of life which is diving rather than flying. Vide book vii. chap. 4. note (*k*).

(*r*) See book v. chap. 2. note (*b*).

would think, for respiration and life) abounding with creatures fitted for it; its bowels abundantly stored, and its surface well bespread. The earth also is plentifully stocked in all its parts, where animals can be of any use; not probably the deepest bowels thereof indeed, being parts in all likelihood unfit for habitation and action, and where a living creature would be useless in the world; but the surface every where abundantly stored.

But that which is most considerable in this matter, and plainly sheweth the divine management in the case, is, that those creatures are manifestly designed for the place in which they are, and the use and services they perform therein. If all the animals of our globe had been made by chance, or placed by chance, or without the divine providence, their organs would have been otherwise than they are, and their place and residence confused and jumbled. Their organs, for instance, of respiration, of vision, and of motion, would have fitted any medium, or have needed none; their stomachs would have served any food, and their blood, and covering of their bodies been made for any clime, or only one clime. Consequently all the animal world would have been in a confused, inconvenient, and disorderly commixture. One animal would have wanted food; another habitation, and most of them safety. They would have all flocked to one or a few places, taken up their rest in the temperate zones only, and coveted one food, the easiest to come at, and most specious in shew; and so would have poisoned, starved, or greatly incommoded one another. But as the matter is now ordered, the globe is equally bespread, so that no place wanteth proper inhabitants, nor any creature is destitute of a proper place, and all things necessary to its life, health, and pleasure. As the surface of the terraqueous globe is covered with different soils, with hills and vales, with seas, rivers, lakes, and ponds, with divers trees and plants, in the several places;

so all these have their animal inhabitants, whose organs of life and action are manifestly adapted to such and such places and things; whose food and phyfic, and every other convenience of life, is to be met with at that very place appointed it. The watery, the amphibious (a), the airy inhabitants, and those on the dry-land surface, and the subterraneous under it, they all live, and act with pleasure, they are gay, and flourish in their proper element and allotted place, they want neither for food, clothing, or retreat; which would dwindle and die, destroy, or poison one another, if all coveted the same element, place, or food.

Nay, and as the matter is admirably well ordered, yet considering the world's increase, there would not be sufficient room, food, and other necessaries for all the living creatures, without another grand act of the divine wisdom, and providence, which is, the balancing the number of individuals of each species of creatures, in that place appointed thereto: of which in the next chapter.

CH A P. X.

Of the BALANCE of Animals, or the due proportion in which the world is stocked with them.

THE whole surface of our globe can afford room and support only to such a number of all sorts of creatures; and if by their doubling, trebling, or any other multiplication of their kind, they should

- (a) Est etiam admiratio nonnulla in bestiis aquatilibus iis, quæ
 • guntur in terra: veluti crocodili, fluviatilesque testudines
 • quædamque serpentes ortæ extra aquam, simul ac primum nati
 • possunt, aquam persequuntur. Quia etiam anatum ova gallinæ
 • sæpe supponimus--[pulli] deinde eas [matres] relinquunt--
 • et effugiunt, cum primum aquam, quasi naturalem domum, tra-
 • dere potuerunt.' Cic. de Nat. Deor. l. 2. c. 48.

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increase to double or treble that number, they must starve, or devour one another. The keeping therefore the balance even, is manifestly a work of the divine wisdom and providence. To which end, the great Author of life hath determined the life of all creatures to such a length, and their increase to such a number, proportional to their use in the world. The life of some creatures is long, and their increase but small, and by that means they do not over-stock the world. And the same benefit is effected, where the increase is great, by the brevity of such creatures lives, by their great use, and the frequent occasions there are of them for food to man, or other animals. It is a very remarkable act of the divine providence, that useful creatures are produced in great plenty (*a*), and others in less. The prodigious and frequent increase of insects, both in and out of the waters, may exemplify the one; and it is observable in the other, that creatures less useful, or by their voracity pernicious, have commonly fewer young, or do seldomer bring forth: of which many instances may be given in the voracious beasts and birds. But there is one so peculiar an animal, as if made for a particular instance in our present case, and that is the cuntur of Peru (*b*); a fowl of that magnitude, strength, and ap-

(*a*) 'Benigna circa hoc natura, innocua et esculenta animalia foecunda generavit.' Plin. Nat. Hist. l. 8. c. 55.

(*b*) 'Captain J. Strong gave me this account, together with a quill feather of the cuntur [or condor] of Peru. On the coast of Chili, they met with this bird in about 33° S. Lat. not far from Mocha, an island in the south-sea—they shot it sitting on a cliff, by the sea-side; that it was 16 feet from wing to wing extended; that the Spanish inhabitants told them they were afraid of these birds, lest they should prey upon their children. And the feather he gave me, saith the doctor, is two feet four inches long; the quill part five inches three quarters long, and one inch and a half about in the largest part. It weighed 3 dr. 17 gr. and a half, and is of a dark-brown colour.' Dr Sloan in Phil. Transf. No. 208.

To this account, the doctor (in a letter to Mr Ray, March 31. 1694. with other papers of Mr Ray's, in my hands) adds the testimony of Jos. Acosta, l. 4. c. 7. and Garcilass. de la Vega,

petite, as to seize not only on the sheep, and lesser cattle, but even the larger beasts, yea, the very children too. Now these, as they are the most pernicious of birds, so are they the most rare, being seldom seen, or only one, or a few in large countries; enough to keep up the species, but not to overcharge the world.

Thus the balance of the animal world, is, throughout all ages, kept even; and by a curious harmony, and just proportion between the increase of all animals, and the length of their lives, the world is through all ages well, but not over-stored: 'One generation passeth away, and another generation cometh (c);' so equally in its room, to balance the stock of the terraqueous globe in all ages and places, and among all creatures; that it is an actual demonstration of our Saviour's assertion, Matth. x. 29, that the most inconsiderable, common creature, 'even a sparrow (two of which are sold for a farthing) doth not fall on the ground without our heavenly Father.'

This providence of God is remarkable in every species of living creatures; but that especial management

who, l. 8. c. 19. saith, 'There are other fowls, called cuntur, and by the Spaniards corruptly condor. Many of these fowls having been killed by the Spaniards, had their proportion taken, and from end to end of their wings measured 15 or 16 feet.---Nature, to temper and allay their fierceness, denied them the talons which are given to the eagle; their feet being tipped with claws like a hen: however, their beak is strong enough to tear off the hide, and rip up the bowels of an ox. Two of them will attempt a cow or bull, and devour him: and it hath often happened, that one of them alone hath assaulted boys of ten or twelve years of age, and eaten them. Their colour is black and white, like a magpye. It is well there are but few of them; for if they were many, they would very much destroy the cattle. They have on the fore-part of their heads, a comb, not pointed like that of a cock; but rather even, in the form of a razor. When they come to alight from the air, they make such a humming noise, with the fluttering of their wings, as is enough to astonish, or make a man deaf.'

(c) Eccles. i. 4.

of the recruits and decay of mankind, so equally all the world over, deserves our especial observation. In the beginning of the world, and so after Noah's flood, the longevity of men, as it was of absolute necessity to the more speedy peopling of the new world; so is a special instance of the divine providence in this matter (*d*). And the same providence appears in the following ages, when the world was very well peopled, in reducing the common age of man then to 120 years (Gen. vi. 3.) in proportion to the occasions of the world at that time. And lastly, when the world was fully peopled after the flood, (as it was in the age of Moses, and so down to our present time), the lessening the common age of man to 70 or 80

(*d*) The divine providence doth not only appear in the longevity of man, immediately after the creation and flood; but also in their different longevity at those two times. Immediately after the creation, when the world was to be peopled by one man, and one woman, the age of the greatest part of those on record was 900 years and upwards. But after the flood, when there were three persons by whom the world was to be peopled, none of these patriarchs, except Shem, arrived to the age of 500; and only the three first of Shem's line, viz. Arphaxad, Salah, and Eber, came near that age; which was in the first century after the flood. But in the second century, we do not find any reached the age of 240. And in the third century, (about the latter end of which Abraham was born), none except Terah, arrived to 200 years: by which time the world was so well peopled, (that part of it at least where Abraham dwelt), that they had built cities, and began to be cantoned into distinct nations and societies, under their respective kings; so that they were able to wage war, four kings against five, Gen. xiv. Nay, if the accounts of Anian, Berosus, Manetho, and others, yea, Africanus, be to be credited, the world was so well peopled, even before the times we speak of, as to afford sufficient numbers for the great kingdoms of Assyria, Egypt, Persia, etc. But learned men generally, with great reason, reject these as legendary accounts.

If the reader hath a mind to see a computation of the increase of mankind, in the three first centuries after the flood, he may find two different ones of the most learned archbishop Usher, and Petavius; together with a refutation of the so early beginning of the Assyrian monarchy; as also reasons for placing Abraham near 1000 years after the flood, in our most learned bishop Stillingfleet's Orig. Sacra, book iii. chap. 4. sect. 9.

years (*e*), (the age mentioned by Moses, Psal. xc. 10. this, I say,) is manifestly an appointment of the

(*e*) That the common age of man hath been the same in all ages since the world was peopled, is manifest from profane, as well as sacred history. To pass by others: Plato lived to the age of 81, and was accounted an old man. And those which Pliny reckons up. l. 7. c. 48. as rare examples of long life, may, for the most part, be matched by our modern histories; especially such as Pliny himself gave credit unto. Dr Plot hath given us divers instances in his history of Oxfordshire, c. 2. sect. 3. and c. 8. sect. 54. and history of Staffordshire, c. 8. sect. 91, etc. Among others, one is of twelve tenants of Mr Biddulph's, that together made 1000 years of age. But the most considerable examples of aged persons among us, is of old Parre of Shropshire, who lived 152 years 9 months, according to the learned Dr Harvey's account; and Henry Jenkins of Yorkshire, who lived 169 years, according to the account of my learned and ingenious friend Dr Tancred Robinson; of both which, with others, see Lowth Abridg. Phil. Transf. v. 3. p. 306. The great age of Parre of Shropshire, minds me of an observation of the reverend Mr Plaxton, that in his two parishes of Kinardsey and Donington in Shropshire, every sixth soul was sixty years of age, or upwards. Phil. Transf. No. 310.

And if we step farther north into Scotland, we shall find divers recorded for their great age: Of which I shall present the reader with only one modern example of one Laurence, who married a wife after he was a 100 years of age, and would go out to sea a-fishing in his little boat, when he was 140 years old; and is lately dead of no other distemper but mere old age, saith Sir Robt Sibbald, Prodr. Hist. Nat. Scot. p. 44. and l. 3. p. 4.

As for foreigners, the examples would be endless; and therefore that of Joh. Ottele shall suffice, who was as famous for his beard, as for being 115 years of age. He was but two Brabant ells and three ninths high, and his long grey beard was one ell and one fourth long. His picture and account may be seen in Ephem. Ger. T. 3. Obs. 163.

As for the story Roger Bacon tells, of one that lived 900 years by the help of a certain medicine, and many other such stories, I look upon them as fabulous. And no better is that of the wandering Jew, named Joh. Buttadaeus, said to have been present at our Saviour's crucifixion; although very serious stories are told of his being seen at Antwerp, and in France, about the middle of the last century but one; and before in anno 1542, conversed with by Paul of Eitsen, bishop of Sleswick; and before that, viz. in 1228, seen and conversed with by an Armenian archbishop's gentleman; and by others at other times.

If the reader hath a mind to see more examples, he may meet with some of all ages, in the learned Hakewill's Apol. p. 186. where he will also find that learned author's opinion of the causes

same infinite Lord that ruleth the world: for by this means, the peopled world is kept at a convenient stay; neither too full, nor too empty. For if men (the generality of them, I mean) were to live now to Methuselah's age of 969 years, or only to Abraham's, long after the flood, of 175 years, the world would be too much over run; or if the age of man was limited to that of divers other animals, to ten, twenty, or thirty years only; the decays then of mankind would be too fast: but at the middle rate mentioned, the balance is nearly even, and life and death keep an equal pace. Which equality is so great and harmonious, and so manifest an instance of the divine management, that I shall spend some remarks upon it.

It appears from our best accounts of these matters, that in our European parts (*f*), and, I believe, the

of the brevity and length of human life. The brevity thereof he attributeth to a too tender education, sucking strange nurses, too hasty marriages; but above all, to luxury, high sauces, strong liquors, etc. The longevity of the ancients he ascribes to temperance in meat and drink, anointing the body, the use of saffron and honey, warm clothes, lesser doors and windows, less physic, and more exercise.

(*f*) The proportions which marriages bear to births, and births to burials, in divers parts of Europe, may be seen at an easy view in this table.

Names of the Places.	Marriages to births: as		Births to burials: as	
England in general	1	to 4 ⁶³	1 ¹²	to 1
London.	1	to 4 ¹	1	to 1 ¹²
Hantshire, from 1569, to 1658.	1	to 4 ¹	1 ²	to 1
Tiverton in Devonsh. 1560, to 1649.	1	to 3 ⁷	1 ²⁶	to 1
Cranbrook in Kent, 1560. to 1649.	1	to 3 ⁹	1 ⁶	to 1
Aynho in Northamptonsh. for 118 years.	1	to 6	1 ⁶	to 1
Seeds in Yorkshire, for 122 years.	1	to 3 ⁷	1 ⁰⁷	to 1
Harwood in Yorkshire, for 57 years.	1	to 3 ⁴	1 ²³	to 1
Upminster in Essex, for 100 years.	1	to 4 ⁶	1 ⁰⁸	to 1
Frankfort on the Main, in 1695.	1	to 3 ⁷	1 ²	to 1
Old, middle, and lower Marck in 1698.	1	to 3 ⁷	1 ⁹	to 1
Domini. of the K. of Prussia in 1698.	1	to 3 ⁷	1 ⁵	to 1
Breslaw in Silesia, from 1687, to 1691.			1 ⁶	to 1
Paris, in 1670, 1671, 1672.	1	to 4 ⁷	1 ¹	to 1 ⁶

same is throughout the world; that, I say, there is a certain rate and proportion in the propagation of mankind: such a number marry (*g*), so many are born, such a number die; in proportion to the number of persons in every nation, country, or parish. And as to births, two things are very considerable: one is the proportion of males and females (*h*), not

Which table I made from Major Graunt's observations on the bills of mortality; Mr King's observations in the first of Dr Davenant's essays; and what I find put together by my ingenious friend, Mr Lowthorp, in his Abridgement, vol. 3. p. 668 and my own register of Upminster. That from Aynho's register in Northamptonshire, I had from the present rector, the learned and ingenious Mr Wasse: and I was promised some accounts from the north, and divers other parts of this kingdom; but have not yet received them: only those of Leeds and Harwood in Yorkshire, from my curious and ingenious friend Mr Thoresby.

(*g*) The preceding table shews, that marriages, one with another, do each of them produce about four births; not only in England, but in other parts of Europe also.

And by Mr King's estimate, the best computations I imagine of any, being derived from the best accounts; such as the marriage, birth, burial-act, the poll-books, etc. by his estimate, I say, about one in 104 marry. For he judgeth the number of the people of England to be about five millions and a half; of which about 41000 annually marry. As to what might be farther remarked concerning marriages, in regard of the rites and customs of several nations, the age to which divers nations limited marriages, etc. it would be endless, and too much out of the way to mention them: I shall only therefore, for the reader's diversion take notice of the jeer of Lactantius, '*Quare apud poetas salacissimus Jupiter desit liberos tollere? utrum sexagenarius factus. et ei lex Papia fibulam imposuit?*' Lact. Instit. l. i. c. 16. By which lex Papia, men were prohibited to marry after 60, and women after 30 years of age.

(*h*) Major Graunt (whose conclusions seem to be well grounded) and Mr King, disagree in the proportions they assign to males and females. This latter makes in London, 10 males to 13 females; in other cities and market-towns, 8 to 9; and in the villages and hamlets, 100 males to 99 females. But Major Graunt, both from the London, and country bills, saith, there are 14 males to 13 females: from whence he justly infers, 'That Christian religion, prohibiting polygamy, is more agreeable to the law of nature than Mahometism, and others that allow it,' chap. 8.

This proportion of 14 to 13, I imagine is nearly just, it being agreeable to the bills I have met with, as well as those in Mr

in a wide proportion, not an uncertain, accidental number at all adventures; but nearly equal. Another thing is, that a few more are born than appear to die, in any certain place (*i*). Which is an admirable provision for the extraordinary emergencies and occasions of the world; to supply unhealthful places, where death out-runs life; to make up the

Graunt. In the 100 years, for example, of my own Parish-regiſter, although the burials of males and females were nearly equal, being 636 males, and 623 females, in all that time; yet there were baptized 709 males, and but 675 females, which is 13 females to 137 males. Which in equality ſhews, not only, that one man ought to have but one wife; but alſo that every woman may, without polygamy, have an husband, if ſhe doth not bar herſelf by the want of virtue, by denial, etc. Alſo this ſurpluſage of males is very uſeful for the ſupplies of war, the ſeas, and other ſuch expences of the men above the women.

That this is a work of the divine providence, and not a matter of chance, is well made out by the very laws of chance, by a perſon able to do it, the ingenious and learned Dr Arbuthnot. He ſuppoſeth Thomas to lay againſt John, that for eighty two years running, more males ſhall be born than females; and giving all allowances in the computation to Thomas's ſide, he makes the odds againſt Thomas, that it doth not happen ſo, to be near five millions of millions, of millions, of millions, to one; but for ages of ages, according to the world's age, to be near an infinite number to one againſt Thomas. Vide. Phil Tranſ No. 338.

(*i*) The foregoing table ſhews, that in England in general, fewer die than are born, there being but 1 death to $1\frac{12}{100}$ births. But in London more die than are born. So by D. Davenant's table the cities likewise and market-towns bury $1\frac{7}{100}$ to one birth. But in Paris they out-do London, their deaths being $1\frac{1}{2}$ to one birth: the reaſon of which I conceive is, becauſe their houſes are more crowded than in London. But in the villages of England, there are fewer die than are born, there being but 1 death to $1\frac{17}{100}$ births. And yet Major Graunt, and Dr Davenant, both obſerve, that there are more breeders in London, and the cities and market-towns, than are in the country, notwithstanding the London births are fewer than the country; the reaſon of which ſee in Graunt, c. 7. and Davenant, ubi ſup.

The laſt remark I ſhall make from the foregoing table, ſhall be, that we may from thence judge of the healthfulneſs of the places there mentioned. If the year 1698 was the mean account of the three Marks, thoſe places bid the faireſt for being moſt healthful; and next to them, Aynho and Cranbrook for Engliſh towns.

ravages of great plagues, and diseases, and the depredations of war, and the seas; and to afford a sufficient number for colonies in the unpeopled parts of the earth. Or, on the other hand, we may say, that sometimes those extraordinary expences of mankind may be not only a just punishment of the sins of men; but also a wise means to keep the balance of mankind even; as one would be ready to conclude, by considering the Asiatic, and other the more fertile countries, where prodigious multitudes are yearly swept away with great plagues, and sometimes war; and yet those countries are so far from being wasted, that they remain full of people.

And now, upon the whole matter, what is all this but admirable and plain management? What can the maintaining, throughout all ages and places, these proportions of mankind, and all other creatures; this harmony in the generations of men be, but the work of one that ruleth the world? Is it possible that every species of animals should so evenly be preserved, proportionate to the occasions of the world; that they should be so well balanced in all ages and places, without the help of almighty wisdom and power? How is it possible by the bare rules, and blind acts of nature, that there should be any tolerable proportion; for instance, between males and females, either of mankind or of any other creature (*k*); especially such as are of a ferine, not of a domestic nature, and consequently out of the command and management of man? How could life and death keep such an even pace through all the animal world? If we should take it for granted, that according to the scripture history, the world had a beginning, as who can deny it (*l*)? or if we should suppose the

(*k*) ' Quid loquar, quanta ratio in bestiis ad perpetuam conservationem earum generis appareat? Nam primum aliae mares, aliae foeminae sunt, quod perpetuitatis causa machinata natura est.' Cic. de Nat. Deor. l. 2. c. 51.

(*l*) Although Aristotle held the eternity of the world, yet he

should be compensated by some other means? That the world should be as well, or better stocked than now it is, in 1656 years, (the time between the creation and the flood; this) we will suppose may be done by the natural method of each species doubling or increase; but in double that number of years, or at this distance from the flood, of 4000 years, that the world should not be over-stocked, can never be made out, without allowing an infinite providence.

I conclude then this observation with the psalmist's words, Psal. civ. 29, 30. 'Thou hidest thy face, all creatures are troubled; thou takest away their breath, they die and return to their dust. Thou sendest forth thy spirit, they are created; and thou renewest the face of the earth.'

C H A P, XI.

Of the Food of Animals.

THE preceding reflection of the psalmist minding me of another thing in common to animals, that pertinently falleth next under consideration, which is, the appointment of food, mentioned in verse 27, 28, of the last cited Psalm civ. 'These [creatures] wait all upon thee, that thou mayst give them their meat in due season. That thou givest them, they gather; thou openest thy hand, they are filled with good.' The same is again asserted in Psal. cxlv. 15, 16. 'The eyes of all wait upon thee, and thou givest them their meat in due season. Thou openest thy hand, and satisfiest the desire of every living thing.'

What the psalmist here asserts, affords us a glorious divines once discoursing with her, she in a passion said, 'She was as certainly damned as this glass is broken,' (throwing a Venice glass against the ground, which she had then in her hand.) But the glass escaped breaking, as credible witnesses attested.

ous scene of the divine providence and management. Which (as I have shewed it to concern itself in other lesser things; so) we may presume doth exert itself particularly in so grand an affair as that of food, whereby the animal world subsists: and this will be manifested, and the psalmist's observations exemplified, from these six following particulars.

I. From the subsisting and maintaining such a large number of animals, throughout all parts of the world.

II. From the proportionate quantity of food to the eaters.

III. From the variety of food suited to the variety of animals: or, the delight which various animals have in different food.

IV. From the peculiar food which peculiar places afford to the creatures suited to those places.

V. From the admirable and curious apparatus made for the gathering, preparing, and digestion of the food. And,

VI. And lastly, From the great sagacity of all animals, in finding out and providing their food.

I. It is a great act of the divine power and wisdom, as well as goodness, to provide food for such a world of animals (a), as every where possess the terraqueous globe; on the dry land, and in the sea and waters; in the torrid and frozen zones, as well as the temperate. That the temperate climates, or at least the fertile valleys, and rich and plentiful regions of the earth, should afford subsistence to many animals, may appear less wonderful perhaps; but that in all other the most unlikely places for supplies, sufficient food should be afforded for such a prodigious number, and so great variety of beasts, birds, fishes, and in-

(a) 'Pastum animantibus large et copiose natura etiam, qui cuique aptus erat, comparavit.' Cic. de Nat. Deor. l. 2. c. 47.

'Ille deus est,—qui per totum orbem armenta dimisit, qui gregibus ubique passim vagantibus pabulum præstat.' Senec. de Senec. l. 4. c. 6.

fects, is owing to that Being, who hath as wisely adapted their bodies to their place and food, as well and carefully provided food for their subsistence there.

But I shall leave this consideration, because it will be illustrated under the following points; and proceed,

II. To consider the adjustment of the quantity of food, in proportion to the eaters. In all places there is generally enough; nay, such a sufficiency, as may be stiled a plenty; but not such a superfluity as to waste and corrupt, and thereby annoy the world. But that which is particularly remarkable here, is, that among the great variety of foods, the most useful is the most plentiful, most universal, easiest propagated, and most patient of weather and other injuries. As the herbacious eaters, for instance, are many, and devour much; so the dry-land surface we find every where almost naturally carpeted over with grass, and other agreeable wholesome plants; propagating themselves in a manner every where, and scarcely destroyable by the weather, the plough, or any part. So likewise for grain, especially such as is most useful, how easily is it cultivated, and what a large increase doth it produce! Pliny's example of wheat (*b*), is a sufficient instance in this matter; which, as that curious heathen observes, being principally useful to the support of man, is easily propagated, and in great plenty: and an happy faculty that is of it, that it can bear either extremes of heat or cold, so as scarce to refuse any clime.

III. Another wise provision the Creator hath made relating to the food of animals, is, that various animals delight in various food (*c*); some in grass and

(*b*) 'Tritico nihil est fertilius: hoc ei natura tribuit, quoniam eo maxime alat hominem; utpote cum e modio, si sit aptum solum -- 150 modii reddantur. Misit D. Augusto procurator -- ex uno grano, vix credibile dictu, 400 paucis minus germinis. Misit et Neroni similiter 340 stipulas ex uno grana.' Plin. Nat. Hist. l. 18. c. 10.

(*c*) 'Sed illa quanta benignitas naturae, quod tam multa ad vescendum, tam varia, tam jucunda gignit; neque ea uno tem-

herbs; some in grain and seeds; some in flesh; some in insects; some in this (*d*), some in that; some more delicate and nice; some voracious and catching at any thing. If all delighted in, or subsisted only with one sort of food, there would not be sufficient for all; but every variety chusing various food, and, perhaps, abhorring that which others like, is a great and wise means that every kind hath enough, and oftentimes somewhat to spare.

It deserves to be reckoned as an act of the divine appointment, that what is wholesome food to one, is nauseous, and as a poison to another; what is a sweet and delicate smell and taste to one, is foetid and lothsome to another; by which means all the provisions the globe affords are well disposed of. Not only every creature is well provided for, but a due consumption is made of those things that otherwise would encumber the world, lie in the way, corrupt, rot, stink, and annoy, instead of cherishing and refreshing it. For our most useful plants, grain, and fruits, would mould and rot; those beasts, fowls, and fishes, which are reckoned among the greatest dainties, would turn to carrion, and poison us: nay, those animals which are become carrion, and many other things that are noisome, both on the dry-land, and in the waters, would be great annoyances, and breed diseases, was it not for the provision which the infinite Orderer of the world hath made,

‘pore anni, ut semper et novitate delectemur et copia.’ Cic. de Nat. Deor. l. 2. c. 53.

(*d*) Swammerdam observes of the Ephemeron-worms, that their food is clay, and that they make their cells of the same. Upon which occasion he saith of moths, that eat wooll and fur, ‘There are two things very considerable, 1. That the cells they make to themselves, wherein they live, and with which, as their house, tortoise-like, they move from place to place, they make of the matter next at hand. 2. That they feed also on the same; therefore when you find their cells, or rather coats or cases, to be made of yellow, green, blew, or black cloth, you will also find their dung of the same colour.’ Swam. Ephem. vita, published by Dr Tyson, chap. 3.

by causing these things to be sweet, pleasant, and wholesome food to some creature or other, in the place where those things fall: to dogs, ravens, and other voracious animals, for instance, on the earth; and to rapacious fishes, and other creatures inhabiting the waters.

Thus is the world, in some measure, kept sweet and clean, and at the same time, divers species of animals supplied with convenient food. Which providence of God, particularly in the supplies afforded the ravens, is divers times taken notice of in the scriptures (*e*); but whether for the reasons now hinted, or any other special reasons, I shall not inquire. Thus our Saviour, Luke xii. 24. 'Consider the ravens; for they neither sow nor reap, which neither have storehouse, nor barn, and God feedeth them.' It is a manifest argument of the divine care and providence, in supplying the world with food and necessities, that the ravens, accounted as unclean, and little regarded by man, destitute of stores, and that live by accidents, by what falleth here and there; that such a bird, I say, should be provided with sufficient food; especially if that be true which Aristotle (*f*), Pliny (*g*), and Ælian (*h*) report, of their unnatural affection and cruelty to their young: 'That they expel them their nests as soon as they can fly, and then drive them out of the country.'

Thus having considered the wise appointment of the Creator, in suiting the variety of food, to variety of animals: let us in the

IV. place, Take a view of the particular food, which particular places afford to the creatures inhabiting therein.

(*e*) Job xxxviii. 41. Psal. cxlviii. 9.

(*f*) Aristot. l. 9. c. 31. Hist. animal.

(*g*) Pliny affirms this of the crow as well as raven: 'Caeterae omnes [i. e. cornices] ex eodem genere pellunt nidis pullos, ac volare cogunt, sicut et corvi, qui—robustos suos foetus fugant longius.' Nat. Hist. l. 10. c. 12.

(*h*) Var. Hist.

It hath been already observed (*i*), that every place on the surface of the terraqueous globe, is stocked with proper animals, whose organs of life and action are curiously adapted to each respective place. Now, it is an admirable act of the divine providence, that every place affords a proper food to all the living creatures therein. All the various regions of the world, the different climates (*k*), the various soils, the seas, the waters, nay, our very putrefactions, and most nasty places about the globe, as they are inhabited by some or other animal, so they produce some proper food or other, affording a comfortable subsistence to the creatures living there. I might for instances (*l*) of this, bring the great variety of herbs, fruits, and grains on the earth, the large swarms of insects in the air, with every other food of the creatures residing in the earth, or flying in the air. But I shall stop

(*i*) Chap. 9.

(*k*) Admiranda naturae dispensatio est, ut aliter, alioque modo, tempore, et industria colatur terra septentrionalis, aliter Æthiopia, etc. Quoad aquilonares, hoc certum est, in plerisque agris Vestrogothorum, parte objecta meridionali plagae, hordeum spatio 36 dierum a semine projecto maturum colligi, hoc est, a fine Junii usque medium Augusti, aliquando celerius. Ea namque maturitas ex soli natura, aerisque clementia, ac humore lapillosum fovente radices, soleque torrente, necessario provenit, ut ita nascatur, ac maturetur, talesque spicae sex ordines in numero aristae habent. Ol. Mag. Hist. l. 15. c. 8. Prata et pascua tanta luxuriant graminum ubertate ac diversitate, ut necessum sit inde arcere jumenta, ne nimio herbarum esu crepent, etc. Id. ib. l. 19. c. 36.

(*l*) Among the many noble contrivances for food, I cannot but attribute that universal aliment, bread, to the revelation, or at least the inspiration of the Creator and Conservator of mankind; not only because it is a food used in all, or most parts of the world; but especially because it is of incomparable use in the great work of digestion, greatly assisting the ferment, or whatever causes the digestion of the stomach. Of which take this example from the noble Mr Boyle. 'He extracted a menstruum from bread alone, that would work on bodies more compact than many hard minerals, nay, even on glass itself, and do many things that aqua-fortis could not do.—Yet by no means was this so corrosive a liquor as aqua-fortis, or as the other acid menstruum.' See the ingenious and learned Dr Harris's Lex. Techn. verbo Menstruum, where the way of preparing it may be met with.

at the waters, because the psalmist, in the forecited civth Psalm, speaks with relation to the special provision for the inhabitants of the waters; and also by reason that many land-animals have their chief maintenance from thence.

Now, one would think, that the waters were a very unlikely element to produce food for so great a number of creatures, as have their subsistence from thence. But yet how rich a promptuary is it, not only to large multitudes of fishes, but also to many amphibious quadrupeds, insects, reptiles, and birds! From the largest leviathan, which the psalmist saith 'playeth in the seas (m),' to the smallest mites in the lakes and ponds, all are plentifully provided for; as is manifest from the fatness of their bodies, and the gaiety of their aspect and actions.

And the provision which the Creator hath made for this service in the waters is very observable; not only by the germination of divers aquatic plants there, but particularly by appointing the waters to be the matrix of many animals, particularly of many of the insect kind, not only of such as are peculiar to the waters, but also of many appertaining to the air and the land, who, by their near alliance to the waters, delight to be about them, and by that means become a prey, and plentiful food to the inhabitants of the waters. And besides these, what prodigious shoals do we find of minute animals, even sometimes discolouring the waters (n)! Of these (not

(m) Psalm civ. 26.

(n) The insects that, for the most part, discolour the waters, are the small insects of the shrimp kind, called by Swammerdam, 'Pulex aquaticus arborescens.' These I have often seen so numerous in stagnating waters in the summer months, that they have changed the colour of the waters to a pale or deep red, sometimes a yellow, according to the colour they were of. Of this Swammerdam hath a pretty story told him by Dr Florence Schuyt, viz. 'Se aliquando studiis intentum, magno quodam et horrifco rumore fuisse turbatum, et simul ad causam ejus inquirendam excitatum; verum se vix cum in finem surrexisset,

(p)

only in the water, but in the air and on land) I have always thought there was some more than ordinary use intended by the all-wise Creator. And having bent many of my observations that way, I have evidently found it accordingly to be. For be they never so numberless or minute, those animals serve for food to some creatures or other. Even those animalcules in the waters, discoverable only with good microscopes, are a repast to others there, as I have often with no less admiration than pleasure seen (o).

But now the usual objection is, that necessity maketh use (p). Animals must be fed, and they

‘ cum ancilla ejus poene exanimis adcurreret, et multo cum singultu referret, omnem Lugduni [Batavorum] aquam esse mutatam in sanguinem.’ The cause of which, upon examination, he found to be only from the numerous swarms of those pulices. Vide Swamm. Hist. Insect p. 70.

The cause of this great concourse and appearance of those little insects, I have frequently observed to be to perform their coit; which is commonly about the latter end of May, and in June. At that time they are very venerous, frisking and catching at one another; and many of them conjoined tail to tail, with their bellies inclined one towards another.

At this time also they change their skin or slough, which I conceive their rubbing against one another mightily promoteth. And what if at this time they change their quarters! See book viii. chap. 4. note (f).

These small insects, as they are very numerous, so are food to many water animals. I have seen not only ducks shovel them up as they swim along the waters, but divers insects also devour them, particularly some of the middle-sized squillae aquaticae, which are very voracious insects.

(o) Besides the pulices last mentioned, there are in the waters other animalcules very numerous, which are scarce visible without a microscope. In May, and the summer months, the green scum on the top of stagnating waters, is nothing else but prodigious numbers of these animalcules: so is likewise the green colour in them, when all the water seems green. Which animalcules, in all probability, serve for food to the pulices aquatici, and other the minuter animals of the waters. Of which I gave a pregnant instance in one of the nymphae of gnats, to my friend the late admirable Mr Ray, which he was pleased to publish in the last edition of his Wisd. of God in the Creat. p. 430.

(p) Nil adeo quoniam natum est in corpore, ut uti Possemus, sed quod natum est, id procreat usum.

And afterwards,

make use of what they find : in the desolate regions, and in the waters, for instance, they feed upon what they can come at ; but, when in greater plenty, they pick and chuse.

But this objection hath been already in some measure answered by what hath been said ; which plainly argues design, and a super-intending wisdom, power and providence in this special business of food. Particularly the different delight of divers animals in different food, so that what is nauseous to one, should be dainties to another, is a manifest argument, that the allotment of food is not a matter of mere chance, but entailed to the very constitution and nature of animals ; that they chuse this, and re-

Propterea capitur cibus, ut suffulciat artus,
Et recreet vireis interdatus, atque patentem
Per membra ac venas ut amorem obturet edendi.

And after the same manner he discourseth of thirst, and divers other things. Vide Lucret. l. 4. v. 831, etc.

Against this opinion of the Epicureans, Galen ingeniously argues in his discourse about the hand. ' Non enim manus ipsæ (saith he) hominem artes docuerunt, sed ratio. Manus autem ipsæ sunt artium organa ; sicut lyra musici—Lyra musicam non docuit, sed est ipsius artifex per eam, qua præditus est, rationem : agere autem non potest ex arte absque organis, ita et una quaelibet anima facultates quasdam a sua ipsius substantia obtinet—Quod autem corporis particulæ animam non impellant, manifeste videre licet, si animalia recens nata consideres, quæ quidem prius agere conantur, quam perfectas habeant particulas. Ego namque bovis vitulum cornibus petere conantem sæpenumero vidi, antequam ei nata essent cornua ; et pullum equi calcitrantem, etc. Omne enim animal suæ ipsius animæ facultates, ac in quos usus partes suæ polleant maxime, nullo doctore, præsentit.—Qua igitur ratione dici potest, animalia partium usus a partibus doceri, cum et antequam illas habeant, hoc cognoscere videantur ? Si igitur ova tria acceperis, unum aquilæ, alterum anatis, reliquum serpentis, et calore modico foveris, animaliaque excluderis ; illa quidem alis volare conantia, antequam volare possint ; hoc autem revolvi videbis, et serpere affectans, quamvis molle adhuc et invalidum fuerit. Et si, dum perfecta erunt, in una eadèmq; domo nutriveris, deinde ad locum subdialelem ducta emisseris, aquila quidem ad sublime ; anas autem in paludem ; ---serpens vero sub terra irrepet. Animalia quidem mihi videntur natura magis quam ratione artem aliquam [τεχνικὰ artificiosa] exercere : apes fingere alveolas, etc. Galen de Usu Part. 1. 11. c. 3.

fuse that, not by accident, or necessity, but because the one is a proper food, agreeable to their constitution, and so appointed by the infinite Contriver of their bodies; and the other is disagreeable and injurious to them.

But all this objection will be found frivolous, and the wisdom and design of the great Creator will demonstratively appear, if we take a survey,

V. Of the admirable and curious apparatus in all animals, made for the gathering, preparing, and digestion of their food. From the very first entrance, to the utmost exit of the food, we find every thing contrived, made and disposed with the utmost dexterity of art, and curiously adapted to the place the animal liveth in, and the food it is to be nourished with.

Let us begin with the mouth. And this we find, in every species of animals, nicely conformable to the use of such a part; neatly sized and shaped for the catching of prey, for the gathering or receiving food (*q*), for the formation of speech, and every other such like use (*r*). In some creatures it is wide and large, in some little and narrow; in some with a deep incisure up into the head (*s*), for the better catching and holding of prey, and more easy com-

(*q*) 'Alia dentibus praedantur, alia unguibus, alia rostri aduncitate carpunt, alia latitudine [eiusdem] ruunt, alia acumine excavant, alia sugunt, alia lambunt, sorbent, mandunt, vorant, Nec minor varietas in pedum ministerio, ut rapiant, distrahant, teneant, premant, pendeant, tellurem scabere non cessent.' Plin. Nat. Hist. l. 10. c. 71.

(*r*) Because it would be tedious to reckon up the bones, glands, muscles, and other parts belonging to the mouth, it shall suffice to observe, that, for the various services of man's mouth, besides the muscles in common with other parts, there are five pair, and one single one proper to the lip only, as Dr Gibson reckons them: but my most diligent and curious friend the late Mr Cowper, discovered a sixth pair. And accordingly Dr Drake reckons six pair, and one single one proper to the lips, l. 3. c. 13.

(*s*) Galen deserves to be here consulted, who excellently argues against the casual concurrence of the atoms of Epicurus and Aëlepiades, from the provident and wise formation of the mouths

minution of hard, large and troublesome food; in others with a much shorter incisure, for the gathering and holding of herbacious food.

In insects it is very notable. In some forcipated, to catch hold and tear their prey (*s*). In some aculeated, to pierce and wound animals (*t*), and suck

of animals, and their teeth answerable thereto. In man, his mouth without a deep incisure, with only one canine tooth on a side, and flat nails, because, saith he, 'Hic natura certo sciebat, se animal mansuetum ac civile effingere cui robur et vires essent ex sapientia, non ex corporis fortitudine' But for lions, wolfs, and dogs, and all such as are called *καρχαρόδοντες*, (or having sharp, serrated teeth), their mouths are large, and deep cut; teeth strong and sharp, and their nails sharp, large, strong, and round, accommodated to holding and tearing. Vide Galen, de Usu Part. l. 11. c. 9.

(*s*) Among insects, the *Squillae aquaticae*, as they are very rapacious, so are accordingly provided for it: particularly the '*Squilla aquatica maxima recurva*,' as I call it, who hath somewhat terrible in its very aspect, and in its posture in the water, especially its mouth which is armed with long, sharp hooks, with which it boldly, and greedily catcheth any thing in the waters, even one's fingers. When they have seized their prey, they will so tenaciously hold it with their forcipated mouth, that they will not part therewith, even when they are taken out of the waters, and jumbled about in one's hand. I have admired at their peculiar way of taking in their food; which is done by piercing their prey with their forceps, which are hollow, and sucking the juice thereof through them.

The *Squilla* here mentioned is the first and second in Mousset's Theat. Insect. l. 2. c. 37.

(*t*) For an instance of insects endued with a spear, I shall, for its peculiarity, pitch upon one of the smallest, if not the very smallest of all the gnat kind, which I call, '*Culex minimus nigricans maculatus sanguisuga*' Among us in Essex, they are called nidiots; by Mousset, midges. It is about one tenth of an inch, or somewhat more, long, with short antennae, plain in the female, in the male feathered, somewhat like a bottle-brush. It is spotted with blackish spots, especially on the wings, which extend a little beyond the body. It comes from a little slender eel-like worm, of a dirty white colour, swimming in stagnating waters by a wrigling motion; as in Fig. 5.

Its *aurelia* is small, with a black head, little short horns, a spotted, slender, rough belly. Vide Fig. 6. It lies quietly on the top of the water, now and then gently wagging itself, this way and that.

These gnats are greedy blood-suckers, and very troublesome, where numerous; as they are in some places near the Thames,

their blood. And in others strongly rigged with jaws and teeth, to gnaw and scrape out their food, to carry burdens (*u*), to perforate the earth, yea the hardest wood, yea, even stones themselves, for houses (*v*) to themselves, and nests for their young.

And lastly, in birds it is no less remarkable. In the first place, it is neatly shaped for piercing the air, and making way for the body through the airy regions. In the next place, it is hard and horny, which is a good supplement for the want of teeth; and causeth the bill to have the use and service of the hand. Its hooked form is of great use to the rapacious kind (*w*), in catching and holding their prey, and in the comminution thereof by tearing; to others it is no less serviceable to their climbing, as well as neat and nice comminution of their food (*x*).

particularly in the Breach-waters, that have lately befallen near us, in the parish of Dagenham; where I found them so vexatious, that I was glad to get out of those marshes. Yea, I have seen horses so stung with them, that they have had drops of blood all over their bodies, where they were wounded by them.

I have given a figure (in Fig. 7.) and more particular description of the gnats, because, although it be common, it is no where taken notice of by any author I know, except Mousset, who, I suppose, means these gnats, which he calls Midges, c. 13. p. 82.

(*u*) Hornets and wasps have strong jaws, toothed, wherewith they can dig into fruits, for their food; as also gnaw and scrape wood, whole mouthfuls of which they carry away to make their combs. Vide infra, chap. 13. note (*c*).

(*v*) Monsieur de la Voye tells of an ancient wall of free-stone in the Benedictines-Abbey at Caen in Normandy, so eaten with worms, that one may run one's hand into most of the cavities: that these worms are small and black, lodging in a greyish shell; that they have large flattish heads, a large mouth, with four black jaws, etc. Phil. Transf. No. 18.

(*w*) 'Pro iis [labris] cornea et acuta volucribus rostra. Eadem rapto viventibus adunca; collecto, recta: herbas ruentibus limumque lata, ut suum generi. Jumentis vice manus ad colligenda pabula: ora apertiora laniatu viventibus.' Plin. Nat. Hist. l. 11. c. 37.

(*x*) Parrots have their bills nicely adapted to these services, being hooked, for climbing and reaching what they have occasion for; and the lower jaw being completely fitted to the hooks of the upper, they can as minutely break their food, as other animals do with their teeth.

Its extraordinary length and slenderness is very useful to some, to search and grope for their food in moorish places (y); as its length and breadth is to others, to hunt and search in muddy places (z); and the contrary form, namely, a thick, short, and sharp-edged bill, is as useful to other birds, who have occasion to husk and flay the grains they swallow. But it would be endless, and tedious, to reckon up all the various shapes, and commodious mechanism of all; the sharpness and strength of those who have occasion to perforate wood and shells (aa); the slenderness and neatness of such as pick up small insects; the cross-form of such as break up fruits (bb), the compressed form of others (cc), with many other curious and artificial forms, all suited to the way of living, and peculiar occasions of the several species of birds. Thus much for the mouth.

(y) Thus in woodcocks, snipes, etc. who hunt for worms in moorish ground, and, as Mr Willoughby saith, live also on the fatty unctuous humour they suck out of the earth. So also the bills of curlews, and many other sea-fowl, are very long, to enable them to hunt for the worms, etc. in the sands on the sea-shore, which they frequent.

(z) Ducks, geese, and divers others, have such long broad bills, to quaffer and hunt in water and mud; to which we may reckon the uncouth bill of the spoon-bill: but that which deserves particular observation in the birds named in these two last notes is, the nerves going to the end of their bills, enabling them to discover their food out of sight; of which see book vii. chap. 2. note (f).

(aa) The *picus viridis*, or green wood-spice, and all the wood-peckers, have bills curiously made for digging wood, strong, hard, and sharp. A neat ridge runs along the top of the green wood-pecker's bill, as if an artist had designed it for strength and neatness.

(bb) The *loxia*, or cross-bill, whose bill is thick and strong, with the tips crossing one another; with great readiness breaks open fir-cones, apples, and other fruit, to come at their kernels, which are its food; as if the crossing of the bill was designed for this service.

(cc) The sea-pie hath a long, sharp, narrow bill, compressed side-ways, and every way so well adapted to the raising limpets from the rocks, which are its chief, if not only food, that nature, or rather the Author of nature, seems to have framed it purely for that use.

Let us next take a short view of the teeth (*dd*). In which their peculiar hardness (*ee*) is remarkable, their growth (*ff*) also, their firm insertion and bandage in the gums and jaws, and their various shape and strength, suited to their various occasions and use (*gg*); the foremost weak and farthest from the centre, as being only preparers to the rest; the others being to grind and mince, are accordingly made stronger, and placed nearer the centre of motion and

(*dd*) 'Those animals which have teeth on both jaws, have but one stomach: but most of those which have no upper teeth, or none at all, have three stomachs; as in beasts, the paunch, the read, and the feck; and in all granivorous birds, the crop, the echinus, and the gizzard. For as chewing is to an easy digestion, so is swallowing whole to that which is more laborious.' Dr Grew's *Cosmol. Sacr.* c. 5. sect 24.

(*ee*) J. Pyper saith, the teeth are made of convolved skins hardened; and if we view the grinders of deer, horses, sheep, &c. we shall find great reason to be of his mind. His observations are, 'Mirum autem eos (i. e. dentes) cum primum e pellibus imbricatis convolutis et mucro viscido contrahantur, in tantam dirigescere soliditatem, quae ossa cuncta superet. Idem fit etiam in ossiculis cerasorum, etc.---Separatione facta, per membranas conditur magna locellis, quos formant laminae tenues, ac duriusculae ad dentis figuram antea divinitus compositae.' Pyper *Merycol.* l. 2. c. 8.

(*ff*) 'Qui autem (i. e. dentes) renascuntur, minime credendum a facultate aliqua plastica brutorum denuo formari, sed latentes tantummodo in conspectum producuntur augmento molis ex effluente succo.' Id. *ibid.*

(*gg*) From these, and other like considerations of the teeth, Men infer, that they must needs be the work of some wise, provident being, not chance, nor a fortuitous concurrence of atoms. For the confirmation of which he puts the case, that suppose the order of the teeth should have been inverted, the grinders set in the room of the incisors, etc. (which might as well have been, and not the teeth been placed by a wise agent), in this case, what would the teeth have been of? what confusion by such a right error in their disposal only? Upon which he argues, 'At quis choream hominum 32 (the number of the teeth) ordine disposuit, eum ut hominem industrium laudaremus: cum vero dentium choream natura tam belle exornavit, nonne ipsam quoque laudabimus?' And then he goes on with the argument, from the sockets of the teeth, and their nice fitting in them, which being no less accurately done, than what is done by a carpenter, or stone-cutter, in fitting a tenon into a mortice, doth well infer the art and act of the wise Maker of animal bodies,

strength. Likewise their various form (*hh*), in various animals, is considerable, being all curiously adapted to the peculiar food (*ii*), and all occasions of the several species of animals (*kk*). And lastly, the temporary defect of them (*ll*), is no less observable in children, and such young creatures, where there is no occasion for them; but they would be rather an annoyance to the tender nipples and breasts.

From the teeth, the grand instruments of mastication

as the other doth the act and art of man. And so he goes on with other arguments to the same effect. Galen de Ufu Part. I. II. c. 8.

(*hh*) A curious account of this may be found in an Extract of a Letter concerning the teeth of divers animals. Printed at Paris, in M. Vougeon's complete body of chirurg. oper. c. 53.

(*ii*) As it hath been taken notice of, that various animals delight in various food; so it constantly falls out, that their teeth are accordingly fitted to their food; the rapacious to catching, holding, and tearing their prey; the herbacious to gathering and comminution of vegetables: and such as have no teeth, as birds, their bill, craw, and gizzard, are assisted with stones, to supply the defect of teeth. But the most considerable example of this kind is in some families of the insect tribes, as the papilio kind, etc. who have teeth, and are voracious, and live on tender vegetables in their nympha, or caterpillar state, when they can only creep; but in their mature papilio state, they have no teeth, but a proboscis, or trunk, to suck up honey, etc. their parts for gathering food, as well as their food, being changed, as soon as they have wings, to enable them to fly to it.

(*kk*) It is remarkable in the teeth of fishes, that in some they are sharp, as also jointed, so as to fall back, the better to catch and hold their prey, and to facilitate its passage into the stomach: so in others they are broad and flat, made to break the shells of snails and shell-fish devoured by them. These teeth, or breakers, are placed, in some, in the mouth; in some, in the throat; and in lobsters, etc. in the stomach itself; in the bottom of whose stomachs are three of these grinders, with peculiar muscles to move them.

(*ll*) What is there in the world can be called an act of providence and design, if this temporary defect of teeth be not such; that children, for instance, should have none whilst they are not able to use them, but to hurt themselves, or the mother; and that at the very age, when they can take in more substantial food, and live without the breast, and begin to need teeth, for the sake of speech; that then, I say, their teeth should begin to appear, and gradually grow, as they more and more stand in need of them.

tion, let us proceed to the other ministerial parts. And here the parotid, sublingual, and maxillary glands, together with those of the cheeks and lips, are considerable; all lodged in the most convenient places about the mouth and throat, to afford that noble digestive salival liquor, to be mixed with the food in mastication, and to moisten and lubricate the passage, to give an easy descent to the food. The commodious form also of the jaws deserves our notice; together with the strong articulation of the lowermost, and its motion. And lastly, the curious form, the great strength, the convenient lodgement and situation of the several muscles and tendons (*mm*), all ministering to this so necessary an act of life, as mastication is; they are such contrivances, such works, as plainly set forth the infinite Workman's care and skill.

Next to the mouth, the gullet presenteth itself; in every creature well-sized to the food it hath occasion to swallow; in some but narrow, in others as large and extensive (*nn*); in all exceedingly remark-

(*mm*) It would be endless to particularize here, and therefore I shall refer to the anatomists; among the rest, particularly to Galen, for the sake of his descant upon this subject. For having described the great accuracy of the contrivance and make of these parts, he saith, 'Haud scio an hominum sit sobriorum ad fortunam opificem id revocare: alioqui quid tandem erat, quod cum providentia atque arte efficitur? Omnino enim hoc ei contrarium esse debet, quod casu ac fortuito sit.' Galen, de Usu Part. l. 11. c. 7. ubi plura.

(*nn*) 'The bore of the gullet is not in all creatures alike answerable to the body or stomach. As in the fox, which both feeds on bones, and swallows whole, or with little chewing; and next in a dog, and other ossivorous quadrupeds, 'tis very large, viz. to prevent a contusion therein. Next in a horse, which though he feeds on grass, yet swallows much at once, and so requires a more open passage. But in a sheep, rabbit, or ox, which bite short, and swallow less at once, 'tis smaller. And in a squirrel, still lesser, both because he eats fine, and to keep him from disgorging his meat upon his descending leaps. And so in rats and mice, which often run along walls, with their heads downwards.' Dr Grew's Comp An. of Stom. and Guts. chap. 5.

able for the curious mechanism of its muscles, and the artificial decussation and position of their fibres (oo).

And now we are arrived to the grand receptacle of the food, the stomach; for the most part as various as the food to be conveyed therein. And here I might describe the admirable mechanism of its tunics, muscles, glands, the nerves, arteries, and veins (pp); all manifesting the super-eminent contrivance and art of the infinite Workman (qq); they being all nicely adjusted to their respective place, occasion, and service. I might also insist upon that most necessary office of digestion; and here consider that wonderful faculty of the stomachs of all creatures, to dissolve (rr) all the several sorts of food appropriated to their species; even sometimes things of that consistency as seem insoluble (ss); especially by such seemingly

(oo) Of this see Dr Willis's Pharm. Rat. Part. 1. sect. 1. c. 1. Steno also, and Peyer. Mery. l. 2.

The description these give of the muscular part of the gullet, the late ingenious and learned Dr Drake saith, is very exact in ruminants, but not in men. 'In men, this coat (the second of the gullet) consists of two fleshy lamellae, like two distinct muscles. The outward being composed of strait longitudinal fibres.—The inner order of fibres is annular, without any observable angles.—The use of this coat, and these orders of fibres, is to promote deglutition; of which the longitudinal, shorten the oesophagus, and so make its capacity larger, to admit of the matter to be swallowed. The annular, on the contrary, contract the capacity, and closing behind the descending aliment, press it downwards.' Drake's Anat. vol. 1. 1. c. 9. (pp) See Willis, ibid. Cowper's Anat. tab. 35. and many other authors.

(qq) 'Promptuarium autem hoc, alimentum universum excipiens, ceu divinum, non humanum sit opificium.' Galen de Usu Part. l. 4. c. 1.

(rr) 'How great a comprehension of the nature of things did it require, to make a menstruum, that should corrode all sorts of flesh coming into the stomach, and yet not the stomach itself, which is also flesh!' Dr Grew's Cosmol. Sacr. c. 4.

(ss) The food of the castor being oftentimes, if not always, dry things, and hard of digestion, such as the roots and bark of trees, it is a wonderful provision made in that creature's stomach, by the digestive juice lodged in the curious little cells there. A description of whose admirable structure and order may be found in Blasius from Wepfer: concerning which he saith, 'In quibus

simple and weak menstrooms as we find in their stomachs: but I shall only give these things a bare mention, and take more particular notice of the special provision made in the particular species of animals, for the digestion of that special food appointed them.

And in the first place, it is observable, that in every species of animals, the strength and size of their stomach (*ss*) is conformable to their food. Such whose food is more delicate, tender, and nutritive, have commonly this part thinner, weaker, and less bulky; whereas such whose aliment is less nutritive, or whose bodies require larger supplies to answer their bulk, their labours, and waste of strength and spirits, in them it is large and strong.

Another very remarkable thing in this part, is, the number of ventricles in divers creatures. In many but one; in some two or more (*tt*). In such

‘ mucus reconditus, non secus ac mel in favis.—Nimirum quia
 ‘ Castoris alimentum exsuccum. et costu disseillimum est, sapien-
 ‘ tissimus et summe admirandus in suis operibus rerum conditor,
 ‘ D. O. M. ipsi pulcherrima ista et assabre facta structura benig-
 ‘ nissime prospexit, ut nunquam deesset fermentum, quod ad sol-
 ‘ vendum, et comminuendum alimentum durum et asperum par
 ‘ foret.’ Vide Blas. Anat. Animal. c. 10. Confer etiam Act. Erud.
 Lips. Ann. 1684. p. 360.

Most of our modern anatomists and physicians attribute digestion to a dissolving menstruum; but Dr Drake takes it to be rather from fermentative, dissolving principles in the aliment itself, with the concurrence of the air and heat of the body; as in Dr Papin’s Digester. Vide Dr Anat. vol. 1. c. 14.

(*ss*) ‘ All carnivorous quadrupeds have the smallest ventricles,
 ‘ flesh going farthest. Those that feed on fruits, and roots, have
 ‘ them of a middle size. Yet the mole, because it feeds unclean,
 ‘ hath a very great one. Sheep and oxen, which feed on grass,
 ‘ have the greatest. Yet the horse, (and for the same reason the
 ‘ coney and hare), though graminivorous, yet comparatively have
 ‘ but little ones. For that a horse is made for labour, and both
 ‘ this, and the hare, for quick and continued motion; for which
 ‘ the most easy respiration, and so the freest motion of the dia-
 ‘ phragm, is very requisite; which yet could not be, should the
 ‘ stomach lie big and cumbersome upon it, as in sheep and oxen
 ‘ it doth.’ Grew. *ibid.* chap. 6.

(*tt*) The dromedary hath four stomachs, one whereof is pe-

as make a sufficient comminution of the food in the mouth, one suffices. But where teeth are wanting, and the food dry and hard, as in granivorous birds, there the defect is abundantly supplied by one thin membranaceous ventricle, to receive and moisten the food, and another thick, strong, muscular one, to grind and tear it (*uu*). But in such birds, and other creatures, whose food is not grain, but flesh, fruits, insects, or partly one, partly the other, there their stomachs are accordingly conformable to their food (*vv*), stronger or weaker, membranaceous or muscular.

But as remarkable a thing as any in this part of animals, is the curious contrivance and fabric of the several ventricles of ruminating creatures. The very act itself of rumination is an excellent provision for the complete mastication of the food, at the resting, leisure times of the animal. But the apparatus for this service, of divers ventricles for its various uses and purposes, together with their curious mechanism, deserves great admiration (*ww*).

Having thus far pursued the food to the place,

cularly endowed with about twenty cavities, like sacks, in all probability for the holding of water. Concerning which, see book vi. chap. 4. note (*a*).

(*uu*) To assist in which office, they swallow small angular stones, which are to be met with in the gizzards of all granivorous birds; but in the gizzard of the iynx, or wry-neck, which was full only of ants, I found not one stone. So in that of the green wood-pecker, full of ants and tree-maggots, there were but few stones.

(*vv*) 'In most carnivorous birds, the third ventricle is membranaceous; where the meat is concocted, as in a man: or somewhat tendinous, as in an owl; as if it were made indifferently for flesh, or other meat, as he could meet with either: or most thick and tendinous, called the gizzard; wherein the meat, as on a mill, is ground to pieces.' Grew, *ubi supra*, c. 9.

(*ww*) It would be much too long a task to insist upon it here as it deserves, and therefore concerning the whole business of rumination, I shall refer to J. Conr. Peyer's *Merycolog. seu de Ruminantibus et Ruminacione commentar.* where he largely treateth of the several ruminating animals, of the parts ministering to this act, and the great use and benefit thereof unto them.

where, by its reduction into chyle, it becomes a proper aliment for the body; I might next trace it through the several mæanders of the guts, the lacteals, and so into the blood (xx), and afterwards into the very habit of the body: I might also take notice of the separation made in the intestines, of what is nutritive, which is received, and what is feculent, being ejected, and the impregnations there from the pancreas and the gall; and after it hath been strained through those curious colanders, the lacteal veins, I might also observe its impregnations from the glands and lymphæducts; and, to name no more, I might farther view the exquisite structure of the parts ministering to all these delicate offices of nature; particularly the

(xx) There are too many particulars to be insisted on, observable in the passages of the chyle, from the guts to the left subclavian vein, where it enters into the blood: and therefore I shall only, for a sample of this admirable oeconomy, take notice of some of the main and more general matters. And,

1. After the food is become chyle, and gotten into the guts, it is an excellent provision made, not only for its passage through the guts, but also for its protrusion into the lacteals, by the peristaltic motion, and valvulae conniventes of the guts. 2. It is an admirable provision, that the mouths of the lacteals, and indeed the lacteals *primi generis* themselves, are small and fine, not wider than the capillary arteries are, lest by admitting particles of the nourishment grosser than the capillaries, dangerous obstructions might be thereby produced. 3. After the reception of the aliment into the lacteals *primi generis*, it is a noble provision for the advancement of its motion, that in the mesenteric glands, it meets with some of the lymphæducts, and receives the impregnation of the lymphæ. And passing on from thence, it is no less an advantage. 4. That the lacteals, and lymphæducts meet in the *receptaculum chyli*, where the aliment-meeting with more of the lymphæ, is made of a due consistence and temperament, for its farther advancement through the thoracic duct, and so into the left subclavian vein and blood. Lastly, This thoracic duct itself is a part of great consideration. For, as Mr Cowper saith, 'If we consider in this duct its several divisions and anastomoses, its numerous valves looking from below upwards; its advantageous situation between the great artery and vertebrae of the back, together with the ducts discharging their re-fluent lymphæ from the lungs, and other neighbouring parts, we shall find all conduce to demonstrate the utmost art of nature used in furthering the steep and perpendicular ascent of the chyle.' *Anat. Introduct.*

artificial conformation of the intestines might deserve a special inquiry, their tunics, glands, fibres traversing one another (yy), and peristaltic motion in all creatures; and their cochleous passage (zz) to retard the motion of the chyle, and to make amends for the shortness of the intestines, in such creatures who have but one gut; together with many other accommodations of nature in particular animals that might be mentioned. But it shall suffice to have given only a general hint of those curious and admirable works of God. From whence it is abundantly manifest, how little weight there is in the former atheistical objection. Which will receive a further confutation from the

VI. And last thing relating to food, that I shall speak of, namely, 'the great sagacity of all animals, in finding out and providing their food.' In man, perhaps, we may not find any thing very admirable, or remarkable in this kind, by means of his reason and understanding, and his supremacy over the inferior creatures; which answereth all his occasions relating to this business; but then even here the Creator hath shewed his skill, in not over-doing the matter; in not providing man with an unnecessary apparatus, to effect over and over again what is feasible, by the reach of his understanding, and the power of his authority.

(yy) These, although noble contrivances and works of God, are too many to be insisted on, and therefore I shall refer to the anatomists, particularly, Dr Willis Pharmaceut. Dr Cole in Phil. Transf. No. 175. and Mr Cowper's elegant cut in Anat. tab. 34. 35. and Append. fig. 39. 40.

(zz) In the thornback, and some other fishes, it is a very curious provision that is made to supply the paucity and brevity of the guts; by the perforation of their single gut, going out straight along, but round like a pair of winding-stairs, so that their gut, which seems to be but a few inches long, hath really a bore of many inches. But of these, and many other noble curiosities and discoveries in anatomy, the reader will, I hope, have a better and larger account from the curious and ingenious Dr Douglas, who is labouring in those matters.

But for the inferior creatures, who want reason, the power of that natural instinct, that sagacity (*aaa*) which the Creator hath imprinted upon them, doth amply compensate that defect. And here we shall find a glorious scene of the divine wisdom, power, providence, and care, if we view the various instincts of beasts, great, and small, of birds, insects, and reptiles (*bbb*). For among every species of them, we may find notable acts of sagacity, or instinct, proportional to their occasions for food. Even among those whose food is near at hand, and easily come at; as grass and herbs; and consequently have no great need of art to discover it; yet, that faculty of their accurate smell and taste, so ready at every turn, to distinguish between what is salutary, and what pernicious (*ccc*), doth justly deserve praise. But for such animals, whose food is not so easily come at, a variety of wonderful instinct may be met with, sufficient to entertain the most curious observer. With what entertaining power and artifice do some creatures

(*aaa*) 'Quibus bestiis erat is cibus, ut alius generis bestiis vescerentur, aut vires natura dedit, aut celeritatem: data est quibusdam etiam machinatio quaedam, atque solertia,' etc. Cic. de Nat. Deor. l. 2. c. 48.

(*bbb*) Among reptiles that have a strange faculty to shift for food, etc. may be reckoned eels, which, although belonging to the waters, can creep on the land from pond to pond, etc. Mr Mosely of Mosely saw them creep over the meadows, like so many snakes from ditch to ditch; which he thought, was not only for bettering their habitation, but also to catch snails in the grass. Plot's History of Staffordshire, c. 7. sect. 32.

And as early as the year 1125, the frost was so very intense, that the eels were forced to leave the waters, and were frozen to death in the meadows. Vide Hawkwill's Apol. l. 2. c. 7. sect. 2.

(*ccc*) 'Enumerare possum, ad pastum capeffendum conficiendumque, quae sit in figuris animantium et quam solers, subtilisque descriptio, partium, quamque admirabilis fabrica membrorum. Omnia enim quae intus inclusa sunt, ita nata, atque ita locata sunt, ut nihil eorum supervacaneum sit, nihil ad vitam retinendam non necessarium. Dedit autem eadem natura belluis et sensum, et appetitum, ut altero conatum haberent ad naturales pastus capeffendos; altero secernerent pestifera a salutaribus.' Cic. de Nat. Deor. l. 2 c. 37. See book iv. c. 4.

hunt (*ddd*), and pursue their game and prey! and others watch and way-lay theirs (*eee*)! With what prodigious sagacity do others grope for it under ground, out of sight, in moorish places, in mud and dirt (*fff*); and others dig and delve for it, both above (*ggg*), and under the surface of the drier

(*ddd*) It would be endless to give instances of my own and others observations, of the prodigious sagacity of divers animals in hunting, particularly hounds, setting dogs, etc. one therefore shall suffice, of Mr Boyle's, viz. 'A person of quality—to make a trial, whether a young blood-hound was well instructed,—caused one of his servants—to walk to a town four miles off, and then to a market-town three miles from thence.—The dog, without seeing the man he was to pursue, followed him by the scent to the above-mentioned places, notwithstanding the multitude of market-people that went along in the same way, and of travellers that had occasion to cross it. And when the blood-hound came to the chief market-town, he passed through the streets, without taking notice of any of the people there, and left not till he had gone to the house, where the man he sought rested himself, and found him in an upper room, to the wonder of those that followed him.' *Boyl. deter. Nat. of Eff. c. 4*

(*eee*) There are many stories told of the craft of the fox, to compass his prey; of which *Ol. Magnus* hath many such, as feigning the barking of a dog, to catch prey near the houses; feigning himself dead, to catch such animals as come to feed upon him; laying his tail on a wasp-nest, and then rubbing it hard against a tree, and then eating the wasps so killed: ridding himself of fleas by gradually going into the water, with a lock of wool in his mouth, and so driving the fleas up into it, and then leaving it in the water; by catching crab fish with his tail, which he saith he himself was an eye-witness of: 'Vidi et ego in Scopulis Norvegiae vulpem, inter rupes immissa cauda in aquas, plures quos invadat.' *Plin. Nat. Hist. l. 8. c. 30.*

But *Pliny's* fabulous story of the hyaena out-does these relations of the fox. 'Sermonem humanum inter pastorum stabula assimulare, nomenque alicujus addiscere, quem evocatum foras laceret. Item vomitionem hominis imitari ad sollicitandos canes quos invadat.' *Plin. Nat. Hist. l. 8. c. 30.*

(*fff*) This do ducks, woodcocks, and many other fowls, which seek their food in dirty, moorish places. For which service they have very remarkable nerves reaching to the end of their bills. Of which see book vii. chap. 2. note (*f*).

(*ggg*) Swine, and other animals that dig, have their noses made more tendinous, callous, and strong for this service, than others that do not dig. They are also edged with a proper, tough border, for penetrating and lifting up the earth; and their nostrils

lands (*bbb*)! And how curious and well designed a provision is it of particular large nerves in such creatures, adapted to that especial service!

What an admirable faculty is that of many animals, to discover their prey at vast distances; some by their smell some miles off (*iii*); and some by their sharp and piercing sight, aloft in the air, or at other great distances (*kkk*)! An instance of the latter of which God himself giveth, (Job xxxix. 27. 28. 29.) in the instinct of the eagle: 'Doth the eagle mount up at thy command, and make her nest on high? She dwelleth and abideth on the rock, upon the crag of the rock, and the strong place (*lll*). From

are placed well, and their smell is very accurate, to discover whatsoever they pursue by digging.

(*bbb*) The mole, as its habitation is different from that of other animals, so hath its organs in every respect curiously adapted to that way of life; particularly its nose made sharp, and slender, but withal tendinous and strong, etc. But what is very remarkable, it hath such nerves reaching to the end of its nose and lips, as ducks, etc. have, mentioned above in note (*fff*). Which pair of nerves I observed to be much larger in this animal than any other nerves proceeding out of its brain.

(*iii*) Predacious creatures, as wolfs, foxes, etc. will discover prey at great distances; so will dogs and ravens discover carrion a great way off by their smell. And if, as the superstitious imagine, the latter flying over and haunting houses be a sign of death, it is no doubt from some cadaverous smell those ravens discover in the air by their accurate smell, which is emitted from those diseased bodies, which have in them the principles of a speedy death.

(*kkk*) Thus hawks and kites on land, and gulls, and other birds, that prey upon the waters, can, at a great height in the air, see mice, little birds and insects on the earth, and small fishes, shrimps, etc. in the waters, which they will dart down upon, and take.

(*lll*) Mr Ray gives a good account of the nidification of the gryllætos. cauda annulo albo cincta. 'Hujus nidus ann. 1662. in sylvis prope Derwentiam, etc. inventus est e bacillis seu virgis ligneis grandioribus compositus, quorum altera extremitas rupis cujusdam eminentiæ, altera duabus betulis innitebatur,—erat nidus quadratus, duas ulnas latus.—In eo pullus unicus, adjacentibus cadaveribus unius agni, unius leporis, et trium grygallorum pullorum.' Synopf. Method. Avium, p. 6 And not only lambs, hares, and grygalli, but Sir Robert Sibbald tells us, they will seize kids and fawns; yea, and children too: of

‘thence she seeketh her prey, and her eyes behold
 ‘afar off.’ What a commodious provision hath the
 Contriver of nature made for animals, that are neces-
 sitated to climb for their food; not only in the struc-
 ture of their legs and feet, and in the strength of
 their tendons and muscles, acting in that particular
 office (*mm*); but also in the peculiar structure of
 the principal parts, acting in the acquess of their
 food (*nn*)! What a provision also is that in nocturnal
 birds and beasts, in the peculiar structure of their
 eye (*oo*), (and we may perhaps add the accuracy of
 their smell too) whereby they are enabled to discover
 their food in the dark! But among all the instances
 we have of natural instinct, those instincts, and e-
 special provisions, made to supply the necessities of
 helpless animals, do, in a particular manner, demon-

which he hath this story of an eagle in one of the Orcades islands
 ‘Quae infantulum unius anni pannis involutum arripuit (quem
 ‘mater tessellas ustibiles pro igne allatura momento temporis de-
 ‘posuerat in loco Houton-head dicto) eumque deportasse per 4
 ‘milliaria passuum ad Hoiam; qua re ex matris ejulatu cognita,
 ‘quatuor viri illuc in navicula profecti sunt, et scientes ubi nidus
 ‘esset, infantulum illaesum et intactum deprehenderunt.’ Prod.
 Nat. Hist. Scot. l. 3. Part. 2. p. 14.

(*mm*) See in book vii. chap. 1. note (*l*), the characteristics
 of the woodpecker-kind.

(*nn*) ‘The contrivance of the legs, feet, and nails [of the o-
 ‘possum], seems very advantageous to this animal in climbing trees,
 ‘which it doth very nimbly, for preying upon birds.’ But that
 which is most singular in this animal, is the structure of its tail,
 to enable it to hang on boughs. ‘The spines, or hooks—in
 ‘the middle of the under side of the vertebrae of the tail, are a
 ‘wonderful piece of nature’s mechanism. The first three verte-
 ‘brae had none of these spines, but in all the rest they were to
 ‘be observed.—They were placed just at the articulation of
 ‘each joint, and in the middle from the sides.—For the per-
 ‘forming this office [of hanging by the tail], nothing, I think,
 ‘could be more advantageously contrived. For when the tail is
 ‘twirled, or wound about a stick, this hook of the spinae easily
 ‘sustains the weight, and there is but little labour of the muscles
 ‘required, only enough for bowing or crooking the tail.’ This,
 and more to the same purpose, see in Dr Tyson’s Anatomy of
 the opossum, in Phil. Trans. No. 239.

(*oo*) See before, chap. 2. notes (*aa*, *bb*), p. 121, and (*cc*) 122.

strate the great Creator's care. Of which I shall give two instances.

1. The provision made for young creatures. That *Στοργή*, that natural affection, so connatural to all, or most creatures towards their young (*ppp*), what an admirable noble principle is it, implanted in them by the wise Creator! By means of which, with what alacrity do they transact their parental ministry! With what care do they nurse up their young; think no pains too great to be taken for them, no dangers (*qqq*) too great to be ventured upon for their

(*ppp*) ' Quid dicam quantus amor bestiarum sit in educandis custodiendisque iis, quae procreaverint, usque ad eum finem, dum possint seipsa defendere!' And having instanced in some animals, where this care is not necessary, and accordingly is not employed, he goes on, ' Jam gallinae, avesque reliquae, et quietum requirunt ad pariendum locum, et cubilia sibi, nidosque construunt, eosque quam possunt mollissime substernunt, ut quam facillime ova servantur. Ex quibus pullos cum excluderint, ita tumentur, ut et pennis foveant, ne frigore laedantur, et si est calor, a sole se opponant.' Cic. de Nat. Deor. l. 2. c. 51. 52.

To this natural care of parent animals to their young, we may add the returns made by the young of some towards the old ones. Pliny saith of rats, ' Genitores suos fessos senecta, alunt insigni pietate.' Nat. Hist. l. 8. c. 57. So cranes, he saith, ' Genitricum senectam invicem educant.' Lib. 18. c. 23.

This St Ambrose takes notice of in his Hexameron, and Ol Magnus, after him, ' Depositi patris artus, per longaeum senectutis plumis nudatos circumstans soboles pennis propriis foveat, —collatitio cibo pascit, quando etiam ipsa naturae reparat dispendia, ut hinc inde senem sublevantes, fulcro alarum suarum ad volandum exercent, et in pristinos usus desueta membra reducant.' For which reason this bird is denominated Pia. Vide Ol Mag. Hist. l. 19. c. 14.

Hereto may be added also the conjugal *Στοργή* of the little green *Æthiopian* parrot, which Mr Ray describes from Clusius. Foemellae senescentes, quod valde notabile vix edere volebant, nisi cibum jam a mare carptum, et aliquandiu in prolobo retentum, et quasi coctum rostro suo exciperent, ut columbarum puli a matre ali solent.' Synops. Meth. Av. p. 32.

(*qqq*) The most timid animals, that at other times abscond, or hastily fly from the face of man, dogs, etc. will, for the sake of their young, expose themselves. Thus among fowls, hens will assault, instead of fly from such as meddle with their brood. So partridges, before their young can fly, will drop frequently

guard and security! How carefully will they lead them about in places of safety, carry them into places of retreat and security; yea some of them admit them into their own bowels (*rrr*)! How will they caress them with their affectionate notes, lull, and quiet them with their tender parental voice, put food into their mouths, suckle them, cherish and keep them warm, teach them to pick, and eat, and gather food for themselves; and, in a word, perform the whole part of so many nurses, deputed by the sovereign Lord and Preserver of the world, to help such young and shiftless creatures, till they are come to that maturity, as to be able to shift for themselves!

And as for other animals, (particularly insects, whose fire is partly the sun, and whose numerous offspring would be too great for their parent-animals care and provision), these are so generated, as to need none of their care, by reason they arrive immediately to their *ἡλικία*, their perfect, adult state, and are able to shift for themselves. But yet, thus far their parental instinct (equivalent to the most rational care and foresight) doth extend, that the old ones do not wildly drop their eggs and sperm any where, at all adventures, but so cautiously reposit it in such commodious places (some in the waters, some on flesh, some on plants) proper and agreeable to their species (*sss*); and some shut up agreeable food in their nests, partly for incubation, partly for food (*sss*),

down, first at lesser, and then at greater distances, to dodge and draw off dogs from pursuing their young.

(*rrr*) The opossum hath a curious bag on purpose for the securing and carrying about her young. There are belonging to this bag two bones, not to be met with in any other skeleton, and four pair of muscles; and some say the teats lie therein also. Dr Tyson. Anat. of the Opossum in Phil. Transf. No. 239. where he also, from Oppian, mentions the dog-fish, that upon any storm or danger, receives the young ones into her belly, which come out again when the fright is over. So also the Squatina and glaucus, the same author saith, have the same care for their young, but receive them into different receptacles.

(*sss*) See book viii. chap. 6.

(*sss*) See chap. 13. note (c).

that their young, in their aurelia or nympha state, may find sufficient and agreeable food to bring them up, till they arrive to their maturity.

Thus far the parental instinct and care.

Next we may observe no less in the young themselves, especially in those of the irrational animals. Forasmuch as the parent-animal is not able to bear them about, to clothe them, and to dandle them, as man doth; how admirably hath the Creator contrived their state, that those poor young creatures can soon walk about, and with the little helps of their dam, shift for, and help themselves! how naturally do they hunt for their teat, suck, pick (*tt*), and take in their proper food!

But for the young of man, their parents reason, joined with natural affection, being sufficient to help to nurse, to feed, and to clothe them; therefore they are born helpless, and are more absolutely, than other creatures, cast upon their parents care (*uuu*). A manifest act and designation of the divine providence!

2. The other instance I promised, is the provision made for the preservation of such animals as are sometimes destitute of food, or in danger of being so. The winter is a very inconvenient, improper season, to afford either food or exercise to insects, and many other animals. When the flowery fields are divested of their gaiety; when the fertile trees and

(*ttt*) There is manifestly a superintending providence in this case, that some animals are able to suck as soon as ever they are born, and that they will naturally hunt for the teat before they are quite got out of the secundines, and parted from the navel-string, as I have seen. But for chickens, and other young birds, they not being able immediately to pick till they are stronger, have a notable provision made for such a time, by a part of the yolk of the egg being inclosed in their belly, a little before their exclusion or hatching, which serves for their nourishment, till they are grown strong enough to pick up meat. Vide book vii. chap. 4. note (*a*).

(*uuu*) 'Qui [infantes] de ope nostra ac de divina misericordia plus merentur, qui in primo statim nativitatis suae ortu plorantes ac flentes, nil aliud faciunt quam deprecantur.' Cypr. Ep. ad Fid.

plants are stripped of their fruits, and the air, instead of being warmed with the cherishing beams of the sun, is chilled with rigid frost; what would become of such animals as are impatient of cold? what food could be found by such as are subsisted by the summer-fruits? But to obviate all this evil, to stave off the destruction and extirpation of divers species of animals, the infinitely wise Preserver of the world hath as wisely ordered the matter; that, in the first place, such as are impatient of cold, should have such a special structure of their body, particularly of their hearts, and circulation of their blood (*vvv*), as during that season, not to suffer any waste of their body, and consequently not to need any recruits; but that they should be able to live in a kind of sleepy, middle state, in their places of safe retreat, until the warm sun revives both them and their food together.

The next provision is for such as can bear the cold, but would want food then; and that is in some by a long patience of hunger (*www*), in others by their

(*vvv*) I might mention here some of the species of birds, the whole tribe almost of insects, and some among other tribes, that are able to subsist for many months without food, and some without respiration too, or very little: but it may suffice to instance only in the land-tortoise; of the structure of whose heart and lungs, see book vi. chap. 5. note (*b*).

(*www*) 'Inediam diutissime tolerat lupus, ut et alia omnia carnivora, licet voracissima; magna utique naturae providentia; quoniam esca non semper in promptu est.' Ray's Syn. Quadr. p. 174.

To the long abstinence mentioned of brute animals, I hope the reader will excuse me, if I add one or two instances of extraordinary abstinence among mankind. One Martha Tayler, born in Derbyshire, by a blow on the back fell into such a prostration of appetite, that she took little sustenance, but some drops with a feather, from Christmas 1667, for thirteen months, and slept but little too all the time. See Dr Thompson's account thereof, in Ephem. Germ. T. 3. obs. 173.

To this we may add the case of S. Chilton, of Tinsbury, near Bath, who, in the years 1693, 1696, and 97, slept divers weeks together. And although he would sometimes, in a very odd manner, take sustenance, yet would lie a long time without any, or with very little, and all without any considerable decay. See Phil. Transf. No. 304.

notable instinct in laying up food before-hand against the approaching winter (*xxx*). Of this many entertaining examples may be given; particularly we may, at the proper season, observe not only the little treasures and holes well stocked with timely provisions, but large fields (*yyy*) here and there throughout bespread with considerable numbers of the fruits of the neighbouring trees, laid carefully up in the earth, and covered safe, by the provident little animals inhabiting thereabouts. And not without pleasure, have I seen and admired the sagacity of other animals, hunting out those subterraneous fruits, and pillaging the treasures of those little provident creatures.

(*xxx*) They are admirable instincts which the *sieur de Beauplau* relates of his own knowledge, of the little animals called *bohaques* in *Ukraine*. 'They make burroughs like rabbits, and in October shut themselves up, and do not come out again till April.—They spend all the winter under ground, eating what they laid up in summer.—Those that are lazy among them, they lay on their backs, then lay a great handful of dry herbage upon their bodies, etc. then others drag those drones to the mouths of their burroughs, and so those creatures serve instead of barrows, etc. I have often seen them practise this, and have had the curiosity to observe them whole days together.—Their holes are parted like chambers; some serve for store-houses, others for burying places, etc. Their government is nothing inferior to that of bees, etc. They never go abroad without posting a centinel upon some high ground, to give notice to the others whilst they are feeding. As soon as the centinel sees any body, it stands upon its hind legs and whistles.' *Beauplau's Description of Ukraine*, in vol. I. of the collection of voyages, etc.

A like instance of the northern *galli sylvestres*, see in chap. 13. note (*g*).

As for the scriptural instance of the ant, see hereafter book viii. chap. 5. note (*d*).

(*yyy*) I have in autumn, not without pleasure observed, not only the great sagacity and diligence of swine, in hunting out the stores of the field-mice; but the wonderful precaution also of those little animals, in hiding their food before-hand against winter. In the time of acorns falling, I have, by means of the hogs, discovered, that the mice had, all over the neighbouring fields, treasured up single acorns in little holes they had scratched, and in which they had carefully covered up the acorn. These the hogs would, day after day, hunt out by their smell.

And now, from this bare transient view of this branch of the great Creator's providence and government, relating to the food of his creatures, we can conclude no less, than that since this grand affair hath such manifest strokes of admirable and wise management, that since this is demonstrated throughout all ages and places, that therefore it is God's handy-work. For, how is it possible that so vast a world of animals should be supported, such a great variety equally and well supplied with proper food in every place fit for habitation, without an especial superintendency and management, equal to, at least, that of the most prudent steward and householder! How should the creatures be able to find out their food when laid up in secret places? And how should they be able to gather even a great deal of the common food, and at last to macerate and digest it, without peculiar organs adapted to the service? And what less than an infinitely wise God could form such a set of curious organs, as we find every species endowed with for this very use? organs so artificially made, so exquisitely fitted up, that the more strictly we survey them, the more accurately we view them, even the meanest of them, with our best glasses, the less fault we find in them, and the more we admire them: whereas the best polished, and most exquisite works, made by human art, appear through our glasses, as rude and bungling, deformed and monstrous; and yet we admire them, and call them works of art and reason. And lastly, what less than rational and wise, could endow irrational animals with various instincts, equivalent, in their special way, to reason itself? Insomuch that some from thence have absolutely concluded, that those creatures had some glimmerings of reason. But it is manifestly instinct, not reason they act by, because we find no varying, but that every species doth naturally pursue at all times the same methods and way, without any tutorage or learning: whereas reason,

without instruction, would often vary, and do that by many methods, which instinct doth by one alone. But of this more hereafter.

C H A P. XII.

Of the CLOTHING of Animals.

HAVING, in the foregoing chapter, somewhat largely taken a view of the infinite Creator's wisdom and goodness towards his creatures, in ordering their food, I shall be more brief in this chapter, in my view of their clothing (*a*); another necessary appendage of life, and in which we have plain tokens of the Creator's art, manifested in these two particulars; the suitableness of animals clothing to their place and occasions; and the garniture and beauty thereof.

I. The clothing of animals is suited to their place of abode, and occasions there; a manifest act of design and skill. For, if there was a possibility, that animals could have been accoutred any other way, than by God that made them, it must needs have come to pass, that their clothing would have been at all adventures, or all made the same mode and way, or some of it, at least, inconvenient and unsuitable. But, on the contrary, we find all is curious and complete, nothing too much, nothing too little, nothing bungling, nothing but what will bear the scrutiny of the most exquisite artist; yea, and so far out-do his best skill, that his most exquisite imitations, even of the meanest hair, feather, scale, or shell, will be found only as so many ugly, ill-made blunders and

(*a*) Concerning the clothing of animals, Aristotle observes, 'That such animals have hair as go on feet, and are viviparous; and that such are covered with a shell, as go on feet, and are oviparous.' Hist. Anim. l. 3. c. 10.

botches, when strictly brought to the test of good glasses. But we shall find an example remarkable enough in the present case, if we only compare the best of clothing which man makes for himself, with that given by the Creator for the covering of the irrational creatures, of which it may be said, as our Saviour doth of the flowers of the field, Matth. vi. 29. 'That even Solomon in all his glory, was not arrayed like one of these.'

But let us come to particulars, and consider the suitableness of the different method the Creator hath taken in the clothing of man, and of the irrational animals. This Pliny (*b*) pathetically laments, and says, 'It is hard to judge, whether nature hath been a kinder parent, or more cruel stepmother to man. For, says he, of all creatures, he alone is covered with other riches; whereas nature hath given various clothing to other animals, shells, hides, prickles, shag, bristles, hair, down, quills, scales, fleeces; and trees she hath fenced with a bark or two against the injuries of cold and heat. Only poor naked man, says he, is in the day of his birth cast into the wide world, to immediate crying and

(*b*) 'Cujus [hominis] causa videtur cuncta alia genuisse natura, magna et saeva mercede contra tanta sua munera: ut non sit satis aestimare, parens melior homini, an tristior noverca fuerit. Ante omnia unum animantium cunctorum alienis velat opibus: caeteris varia tegumenta tribuit, testas, cortices, coria, spinas, villos, setas, pilos, plumam, pennas, squamas, vellera. Truncos etiam arboreosque cortice, interdum gemino, a frigore, et calore tutata est. Hominem tantum nudum, et in nuda humo, natali die abjicit ad vagitus statim et ploratum, nullumque tot animalium aliud ad lacrymas, et has protinus vitae principio.' Plin. Nat. Hist. l. 7. Proem.

Let Seneca answer this complaint of Pliny, although perhaps what he saith might be more properly noted in another place: 'Quisquis es iniquus aestimator sortis humanae, cogita quanta nobis tribuerit parens noster, quanto valentiora animalia sub jugum miserimus, quanto velociora assequamur, quam nihil sit mortale non sub ictu nostro positum. Tot virtutes accepimus, tot artes, animum denique cui nihil non eodem quo intendit momento pervitum est, sideribus velociorem,' etc. Sen. de Ben. l. 2. c. 29.

‘squalling; and none of all creatures besides so soon to tears in the very beginning of their life.’

But here we have a manifest demonstration of the care and wisdom of God towards his creatures; that such should come into the world with their bodies ready furnished and accommodated, who had neither reason nor forecast to contrive, nor parts adapted to the artifices and workmanship of clothing; but for man, he being endowed with the transcending faculty of reason, and thereby made able to help himself, by having thoughts to contrive, and withal hands to effect, and sufficient materials (c) afforded

(c) ‘*Mirantur plurimi quomodo tute, et sane vivant homines in horrendis frigoribus plagae septentrionalis; hancque levem quaestionem ultra 30 annos audieram in Italia, praesertim ab Aethiopibus, et Indis, quibus onerosus videtur vellitus subzona torrida—Quibus respondetur,—gaudet Indus multiplici plumarum genere, magis forsan pro tegumento, quam necessitate: rursus Scythia villosa vestitu.—Ita sub polo arctico adversus asperissimas hyemes—opportuna remedia facilius administrat [natura], ligna videlicet in maxima copia, et levissimo pretio, et demum pelles diversorum animalium, tam sylvestrium quam domesticorum.*’ Then he gives a catalogue of them, and saith, ‘*Quorum omnium experti pellifices ita ingeniose noverunt mixturas componere, ut pulcherrimum decorem ostendat varietas, et callidissimum fomentum adjuncta mollietis.*’ *Ol. Mag. Hist. l. 6. c. 20.*

To this guard against the cold, namely, of fire and clothing, I hope the reader will excuse me, if I take this opportunity of adding some other defensatives, nature, or rather the great Author of nature, hath afforded these northern regions: such are their high mountains, abounding, as *Ol. Magnus* saith, through all parts; also their numerous woods, which, besides their fire, do, with the mountains, serve as excellent screens against the cold piercing air, and winds. Their prodigious quantities of minerals, and metals, also afford heat, and warm vapours. ‘*Minerae septentrionalium regionum satis multae, magnae, diversae, et opulenter sunt,*’ saith the same curious, and, for his time, learned archbishop, *l. 6. c. 1.* and in other places. And for the warmth they afford, the volcanos of those parts are an evidence; as are also their terrible thunder and lightning, which are observed to be the most severe and mischievous in their metalline mountains, in which large herds of cattle are sometimes destroyed; the rocks so rent and shattered, that new veins of silver are thereby discovered; and a troublesome kind of quinsy is produced in their throats, by the stench, and poisonous nature of the sulphureous

him from the skins and fleeces of animals, and from various trees and plants: man, I say, having all this provision made for him, therefore the Creator hath wisely made him naked, and left him to shift for himself, being so well able to help himself.

And a notable act this is of the wisdom of God, not only as the mere setting forth his care and kindness to them that most needed his help, the helpless irrational animals, and in his not over-doing his work; but also as it is most agreeable to the nature and state of man (*d*), both on natural and political accounts. That man should clothe himself, is most

vapours, which they dissolve, by drinking warm beer and butter together, as Olaus tells us in the same book, chap. 11.

To all which defensatives I shall in the last place add, the warm vapours of their lakes, (some of which are prodigiously large, of 130 Italian miles in length, and not much less in breadth); also of their rivers, especially the vapours which arise from the sea. Of which guard against severe cold, we have lately had a convincing proof in the great frost, in 1708, wherein, when England, Germany, France, Denmark yea, the more southerly regions of Italy, Switzerland, and other parts, suffered severely, Scotland and Ireland felt very little of it hardly more than in other winters; of the particulars of which, having given an account in the Phil. Transf. No. 324 I shall thither refer the reader. But, it seems, this is what doth ordinarily befall those northern parts; particularly the islands of Orkney, of which the learned Dr Wallace gives this account: 'Here the winters are generally more subject to rain than snow; nor doth the frost and snow continue so long here as in other parts of Scotland; but the wind in the mean time will often blow very boisterously; and it rains sometimes, not by drops, but by spouts of water, as if whole clouds fell down at once. In the year 1680, in the month of June, after great thunder, there fell flakes of ice near a foot thick.' Wall. Account of Orkney, chap. 1. p. 4. From which last passage I observe, that although in those parts, the atmosphere near the earth be warm, it is excessively cold above, so as to freeze some of those spouts of water in their descent, into such great, and almost incredible, masses of hail. And whence can this warmth proceed, but from the earth, or sea, emitting heat sufficient to stave off the cold above? Consult book ii. chap. 5. note (*f*), p. 77.

(*d*) 'Sicut enim si innata sibi [i. e. homini] aliqua haberet arma, illa ei sola semper adessent, ita et si artem aliquam natura fortitus essent, reliquas sane non haberet. Quia vero ei melius erat omnibus armis omnibusque artibus uti, neutrum

agreeable to his nature, particularly, among other things, as being most salutary, and most suitable to his affairs. For, by this means, man can adapt his clothing to all seasons, to all climates, to this, or to any business. He can hereby keep himself sweet and clean, fence off many injuries; but above all, by this method of clothing, with the natural texture of his skin adapted to it, it is that the grand means of health, namely, insensible perspiration (e), is performed, at least greatly promoted, without which an human body would be soon overrun with diseases.

In the next place, there are good political reasons for man's clothing himself; inasmuch as his industry is hereby employed in the exercises of his art and ingenuity; his diligence and care are exerted in keeping himself sweet, cleanly, and neat; many callings and ways of life arise from thence; and, to name no more, the ranks and degrees of men are hereby, in some measure, rendered visible to others, in the several nations of the earth.

Thus it is manifestly best for man, that he should clothe himself.

But for the poor shiftless irrationals, it is a prodi-

eorum a natura ipsi propterea datum est. Gal. de Usu Part. l. 1. c. 4.

(e) Concerning insensible perspiration, Sanctorius observes, that it much exceeds all the sensible put together. De Stat. Med. Aph. 4. That as much is evacuated by insensible perspiration in one day, as is by stool in fourteen days: particularly, that, in a night's time, about sixteen ounces is commonly sent out by urine, four ounces by stool; but above forty ounces by insensible perspiration. Aphor. 59. 60. That if a man eats and drinks eight pounds in a day, five pounds of it is spent in insensible perspiration. Sect. 1. Aph. 6. And as to the times, he saith, 'Ab assumpto cibo 5 horis 1 lb circiter perspirabilis—exhalare solet, a 5a ad 12am 3 lb circiter; a 12a ad 16am vix selibram.' Aph. 56.

And as to the wonderful benefits of insensible perspiration, they are abundantly demonstrated by the same learned person, *ibi supra*; as also by Borelli in his second part, De Mor. Animal, prop. 168. who saith, 'Necessaria est insensibilis transpiratio, ut vita animalis conservetur.'

gious act of the great Creator's indulgence, that they are all ready furnished with such clothing, as is proper to their place and business (*f*). Some covered with hair (*g*), some with feathers (*h*), some with scales,

(*f*) 'Animantium vero quanta varietas est! Quanta ad eam rem vis, ut in suo quaque genere permaneant! Quarum aliae coriis testae sunt, aliae villis vestitae, aliae spinis hirsutae: pluma aliae, aliae squama videmus obductas, aliae esse cornibus armatas, aliae habere effugia pennarum.' Cic. de Nat. Deor. l. 2. c. 47.

(*g*) From Malpighi's curious observations of the hair, I shall note three things: 1. Their structure is fistulous, or tubular; which hath long been a doubt among the curious. 'Fistulosum [esse pilum] demonstrat lustratio pilorum a cauda et collo equorum, etc.—praecipue setarum apri, quae patentiorẽ ex fistulis compositionem exhibent. Est autem dictus apri pilus cylindricum corpus quasi diaphanum—fistularum aggere conflatum, et speciem columnae striatae prae se fert. Componentes fistulae in gyrum situae in apice patentiores redduntur; nam hians pilus in geminas dividitur partes, et componentes minimae fistulae—liberiorẽs redditae manifestantur, ita ut enumerari possint; has autem 20, et ultra numeravi.—Expositae fistulae—tubulosae sunt, et frequentibus tunicis transversaliter situatis, veluti valvulis pollent. Et quoniam spinae, in erinaceis praecipue, etc. nil aliud sunt, quam duri et rigidi pili, ideo,' etc. And then he describes the hedgehog's spines, in which those tubes manifestly appear; together with medullary valves and cells; not inelegant, which he hath figured in tab. 16. at the end of his works.

That which this sagacious, and not enough to be commended observer, took notice of in the structure of hair, and its parity to the spines, I have myself observed, in some measure to be true, in the hair of cats, rats, mice, and divers other animals; which look very prettily when viewed with a good microscope. The hair of a mouse, the most transparent of any I have viewed, seems to be one single transparent tube, with a pith made up of a fibrous substance, running in dark lines; in some hairs transversely, in others spirally, as in Fig. 14, 15, 16, 17. These darker medullary parts, or lines, I have observed, are no other than small fibres convolved round, and lying closer together than in other parts of the hair. They run from the bottom to the top of the hair; and, I imagine, serve to the gentle evacuation of some humour out of the body; perhaps, the hair serves as well for the insensible perspiration of hairy animals, as to fence against cold and wet. In Fig. 14, 16. is represented the hair of a mouse, as it appears through a small magnifier; and in Fig. 15, 17. as it appears when viewed with a larger magnifier.

Upon another review, I imagine, that although in Fig. 14, 15. the dark parts of the pith seem to be transverse, that they, as well as in the two other figures, run round in a screw-like fashion.

(*h*) See book vii. chap. 1. note (*d*), and (*e*).

some with shells (*i*), some only skin, and some with firm and stout armature: all nicely accommodated to the element in which the creature liveth, and its occasions there (*k*). To quadrupeds hair is a commodious clothing; which, together with the apt texture of their skin, fitteth them for all weathers to lie on the ground, and to do the offices of man: and the thick and warm furs and fleeces of others are not only a good defenſative againſt the cold and wet; but alſo a ſoft bed to reſoſe themſelves in; and to many of them a comfortable covering, to nurſe and cheriſh their tender young.

And as hair to quadrupeds, ſo feathers are as commodious a dreſs to ſuch as fly in the air, to birds, and ſome inſects; not only a good guard againſt wet and cold, and a comfortable covering to ſuch as hatch and brood their young; but alſo moſt commodious for their flight. To which purpoſe they are nicely and neatly placed every where on the body, to give them an eaſy paſſage through the air (*l*), and to aſſiſt in the waſting their body through that thin medium. For which ſervice, how curious is their texture for lightneſs, and withal for ſtrength! Hollów and thin

(*i*) See chap. 14. note (*c*).

(*k*) It is a ſign ſome wiſe Artiſt was a contriver of the clothing of animals, not only as their clothing varies, as their way of living doth; but alſo becauſe every part of their bodies is furniſhed with proper ſuitable clothing. Thus divers animals, that have their bodies covered for the moſt part with ſhort, ſmooth hair, have ſome parts left naked, where hair would be an annoyance; and ſome parts beſet with long hair, as the mane and tail; and ſome with ſtiff, ſtrong bristles, as about the noſe; and ſometimes within the noſtrils, to guard off, or give warning of annoyances.

(*l*) The feathers being placed from the head towards the tail, in cloſe and neat order, and withal preened and dreſſed by the contents of the oil-bag, afford as eaſy a paſſage through the air, as a boat new cleaned and dreſſed finds in its paſſage through the waters. Whereas, were the feathers placed the contrary, or any other way, (as they would have been, had they been placed by chance, or without art), they would then have gathered air, and been a great incumbrance to the paſſage of the body through the air. See book vii. chap. 1. note (*b*).

for lightness, but withal, context and firm for strength. And where it is necessary they should be filled, what a light and strong medullary substance is it they are filled with ! By which curious contrivances, even the very heaviest parts made for strength, are so far from being a load to the body, that they rather assist in making it light and buoyant, and capacitate it for flight. But for the vanes, the lightest part of the feather, how curiously are they wrought with capillary filaments neatly interwoven together (*m*), whereby they are not only light, but also sufficiently close and strong, to keep the body warm, and guard it against the injuries of weather, and withal, to impower the wings, like so many sails, to make strong impulses upon the air in their flight (*n*). Thus curious, thus artificial, thus commodious is the clothing of beasts and birds ! concerning which, more in its proper place.

And no less might I shew that of reptiles and fishes (*o*) to be, if it was convenient to enlarge upon this branch of the Creator's work. How well adapted are the annuli of some reptiles, and the contortions of the skin of others, not only to fence the body sufficiently against outward injuries, but to enable them to creep, to perforate the earth (*p*) ! and, in

(*m*) In book vii. chap. i. note (*c*), there is a particular account of the mechanism of their vanes, from some nice microscopical observations, and therefore I shall take no farther notice of it here.

(*n*) Vide Borell. de Mot. Animal. Prop. 182. vol. 1.

(*o*) See book ix.

(*p*) For a sample of this branch of my survey, let us chuse the teguments of earth-worms, which we shall find completely adapted to their way of life and motion, being made in the most complete manner possible for terebrating the earth, and creeping where their occasions lead them : for their body is made throughout of small rings, and these rings have a curious apparatus of muscles, enabling those creatures with great strength to dilate, extend, or contract their annuli, and whole body ; those annuli also are each of them armed with small, stiff, sharp beards, or prickles, which they can open, to lay hold on, or shut up close to their body : and lastly, under the skin there lies a slimy juices

a word, to perform all the offices of their reptile state, much better than any other tegument of the body would do ! And the same might be said of the covering of the inhabitants of the waters, particularly the shells of some, which are a strong guard to the tender body that is within, and consistent enough with their slower motion ; and the scales and skins of others, affording them an easy and swift passage through the waters. But it may be sufficient to give only a hint of these things, which more properly belong to another place.

Thus hath the indulgent Creator furnished the whole animal world with convenient, suitable clothing.

II. Let us, in the next place, take a short view of the garniture (*q*), and beauty thereof. And here we shall thus far, at least, descry it to be beautiful ; that it is complete and workman-like. Even the clothing of the most sordid animals, those that are the least beautified with colours, or rather whose clothing may regrade the eye (*r*) ; yet when we come strictly to view them, and seriously consider the nice mechanism of one part, the admirable texture of another, and the exact symmetry of the whole ; we discern such strokes of inimitable skill, such incompa-

that they emit, as occasion is, at certain perforations between the annuli, to lubricate the body, and facilitate their passage into the earth. By all which means they are enabled, with great speed, ease, and safety, to thrust and wedge themselves into the earth, which they could not do, had their bodies been covered with hair, feathers, scales, or such like clothing of the other creatures. See more concerning this animal, book ix. chap. i. note (*k*).

(*q*) Aristotle, in his Hist. Anim. l. 3. c. 12. names several rivers, that by being drank of, change the colour of the hair.

(*r*) For an example, let us take the clothing of the tortoise and viper ; because, by an incurious view, it rather regrateth, than pleaseth the eye ; but yet, by an accurate survey, we find the shells of the former, and the scales of the latter, to be a curious piece of mechanism, neatly made, and so completely, and well put and tacked together, as to exceed any human compositions of the latter ; see more in book ix. chap. i. note (*c*).

rable curiosity, that we may say with Solomon, Eccl. iii. 11. ' [God] hath made every thing beautiful in his time.'

But for a farther demonstration of the super-eminent dexterity of his almighty hand, he hath been pleased, as it were on purpose, to give surprising beauties to divers kinds of animals. What radiant colours are many of them, particularly some birds and insects (*f*), bedecked with ! What a prodigious combination is there often of these, yea, how nice an air frequently of meaner colours (*s*), as to captivate the eye of all beholders, and exceed the dexterity of the most exquisite pencil to copy !

And now, when we thus find a whole world of animals, clothed in the wisest manner, the most suitable to the element in which they live, the place in which they reside, and their state and occasions there ; when those that are able to shift for themselves, are left to their own discretion and diligence, but the helpless well accoutered and provided for ; when such incomparable strokes of art and workmanship appear in all, and such inimitable glories and beauties in the clothing of others ; who can with the greatest obstinacy and prejudice deny this to be God's handy-work ? The gaudy, or even the meanest apparel, which man provideth for himself, we readily enough own to be the contrivance, the work of man : and shall we deny the clothing of all the animal world besides (which infinitely surpasseth all the robes of earthly majesty ; shall we, dare we, deny that) to be

(*f*) It would be endless to enter into the particulars of the beautiful birds and insects of our European parts ; but especially those inhabiting the countries between the tropics, which are observed as much to exceed our birds in their colours, as ours do theirs in their singing.

(*s*) The wryneck, at a distance, is a bird of mean colour ; neither are indeed its colours radiant, or beautiful, singly considered : but when it is in the hand, we see its light and darker colours so curiously mixed together, as to give the bird a surprising beauty. The same is also observable in many insects, particularly of the phalaena kind.

the work of any thing less than of an infinite, intelligent Being, whose art and power are equal to such glorious work !

CH A P. XIII.

Of the HOUSES and HABITATION of Animals.

HA V I N G, in the last chapter, as briefly as well I could, surveyed the clothing of animals, I shall in this take a view of their houses, nests, their cells and habitations, another thing no less necessary to their well-being than the last ; and in which the great Creator hath likewise signalized his care and skill, by giving animals an architectonic faculty, to build themselves convenient places of retirement, in which to repose and secure themselves, and to nurse up their young.

And here, as before, we may consider the case of man, and that of the irrational animals. Man having, as I said, the gift of reason and understanding, is able to shift for himself, to contrive and build, as his pleasure leads him, and his abilities will admit of. From the meanest huts and cottages, he can erect himself stately buildings, bedeck them with exquisite arts of architecture, painting, and other garniture ; ennoble them, and render them delightful with pleasant gardens, fountains, avenues, and what not. For man therefore the Creator hath abundantly provided in this respect, by giving him an ability to help himself. And a wise provision this is, inasmuch as it is an excellent exercise of the wit, the ingenuity, the industry, and care of man.

But since ingenuity, without materials, would be fruitless, the materials therefore which the Creator hath provided the world with, for this very service of building, deserve our notice. The great varieties of

trees (a), earth, stones, and plants, answering every occasion and purpose of man for this use, in all ages and places all the world over, is a great act of the Creator's goodness; as manifesting, that since he has left man to shift for himself, it should not be without sufficient helps to enable him to do so, if he would but make use of them, and the sense and reason which God hath given him.

Thus sufficient provision is made for the habitation of man.

And no less shall we find is made for the rest of the creatures; who, although they want the power of reason to vary their methods, and cannot add to, or diminish from, or any way make improvements upon their natural way, yet we find that natural instinct which the Creator's infinite understanding hath imprinted in them, to be abundantly sufficient, nay, in all probability, the very best or only method they can take, or that can be invented, for the respective use and purpose of each peculiar species of animals (b). If some creatures make their nests in houses, some in trees, some in shrubs, some in the earth (c), some in stone, some in the waters,

(a) ————— Dant utile lignum
 Navigiis pinos, domibus cedrosque, cupressosque :
 Hinc radios trivere rotis, hinc tympana plaustris
 Agricolaë, et pandas ratibus posuere carinas.
 Viminibus salices foecundae, frondibus ulmi;
 At myrtus validis hastilibus, et bona bello
 Cornus; Ityraeos taxi torquentur in arcus.
 Nec tiliæ leves, aut torno rasile buxum,
 Non formam accipiunt, ferroque cavantur acuto :
 Necnon et torrentem undam levis innatat alnus
 Missa Pado : necnon et apes examina conduunt
 Corticibusque cavis, vitiosaeque illicis alveo.

Virg. Georg. l. 2. carm. 44b

(b) See chap. 15. and book viii. chap. 6.

(c) Many of the vespaë ichneumones are remarkable enough for their nidification and provision for their young. Those that build in earth (which commonly have golden and black rings round their alvi) having lined the little cells they have perforated, lay therein their eggs, and then carry into them maggots from the leaves of trees, and seal them up close and neatly.

some here, and some there, or have none at all; yet we find, that that place, that method of nidification, doth abundantly answer the creatures use and occasions. They can there sufficiently and well repose, and secure themselves, lay, and breed up their young. We are so far from discovering any inconvenience in any of their respective ways, from perceiving any loss befall the species, any decay, any perishing of their young; that, in all probability, on the contrary, in that particular way, they better thrive, are more secure, and better able to shift for, and help themselves. If, for instance, some beasts make to themselves no habitation, but lie abroad in the open air, and there produce their young; in this case we find there is no need it should be otherwise, by reason they are either taken care of by man (*d*),

And another ichneumon, more of the vespa than musca-ichneumon kind, (having a little sting in its tail, of a black colour), gave me the pleasure, one summer, of seeing it build its nest in a little hole in my study-window. This cell was coated about with an odoriferous, resinous gum, collected, I suppose, from some fir-trees near; after which it laid two eggs, I think the number was, and then carried in divers maggots, some bigger than itself. These it very sagaciously sealed close up into the nest, leaving them there, doubtless, partly to assist the incubation; and especially for food to the future young, when hatched.

Of this artifice of these ichneumons, Aristotle himself takes notice, (but I believe he was scarce aware of the eggs sealed up with the spiders.) *Οι δὲ Σφήκες Ιχνημόνες καλυμμένοι*, etc. 'As to the vespae, called ichneumones, less than others, they kill spiders, and carry them into their holes, and heaving sealed them up with dirt, they therein hatch, and produce those of the same kind.' Hist. Anim. l. 5. c. 20.

To what hath been said about these ichneumon wasps, I shall add one observation more, concerning the providential structure of their mouth in every of their tribes, viz. their jaws are not only very strong, but nicely sized, curved, and placed for gnawing and scraping those complete little holes they perforate in earth, wood, yea, in stone itself.

(2) Tully having spoken of the care of some animals towards their young, by which they are nursed and brought up, saith, 'Accidit etiam, ad nonnullorum animantium, et earum rerum, quas terra gignit, conservationem, et salutem, hominum etiam solertia et diligentia. Nam multae et pecudes, et stirpes sunt,

or in no danger, as other creatures, from abroad. If others reposit their young in holes (*e*) and dens, and secure themselves also therein, it is, because such guard, such security, is wanting, their lives being sought either by the hostility of man, or to satisfy the appetite of rapacious creatures (*f*) If among birds, some build their nests close, some open, some with this, some with another material, some in houses, some in trees, some on the ground (*g*), some on rocks and crags on high, (of which God himself hath given an instance in the eagle, Job xxxix. 27. 28.) And so among the insect and reptile kinds, if some reposit their eggs or young in the earth, some in wood, some in stone, some on one kind of plant, some on another, some in warm and dry places, some in the water, and moist places, and some in their own bodies only, as shall be shewn in proper place; in all these cases it is, in all probability, the best or only method the animal can take for the hatching, and production of its young, for their supplies, safety, or some other main point of their being

* quae sine procuracione hominum salvae esse non possunt.' Cic. de Nat. Deor. l. 2. c. 32.

(*e*) Prov. xxx. 26. 'The conies are but a feeble folk, yet make they their houses in the rocks.'

(*f*) See note (*h*), p. 236.

(*g*) It is a notable instinct which Ol. Magnus tells of the galli sylvestres, in his northern country, so secure themselves against the cold and storms of the winter. 'Cum nivis instar collium terrae superficiem ubique cooperiunt, ramosque arborum diutius deprimunt et condensant, certos fructus betulae arboris—in forma longi piperis vorant, et glutunt indigestos; idque tanta aviditate, ac quantitate, ut repletum guttur toto corpore majus appareat. Deinde partitis agminibus sese inter medios nivium colles immergunt, praesertim, in Jan. Febr. Martio, quando nives ut turbines, typhones, vel tempestates gravissimae e nubibus descendunt. Cumque coopertae sunt,—certis hebdomadis cibo in gutture collecto, egesto, et resumpto vivunt, venatorum canibus non produntur.—Quod si praesentiunt nivem imminere majorem, praedicto fructu interum devorato, aliud domesticum micilium captant, in eoque manent usque ad finem Martii,' etc. Ol. Mag. Hist. l. 19. c. 33.

or well-being. This is manifest enough in many cases, and therefore probable in all. It is manifest that such animals, for instance, as breed in the waters, (as not only fish, but divers insects, and other land-animals do), that their young cannot be hatched, fed, or nursed up in any other element. It is manifest also, that insects, which lay their eggs on this, and that, and the other agreeable tree, or plant, or in flesh, etc. that it is by that means their young are fed and nursed up. And it is little to be doubted also, but that these matrixes may much conduce to the maturation and production of the young. And so in all other the like cases of nidification, of heat or cold, wet or dry, exposed or open, in all probability this is the best method for the animal's good, most salutary and agreeable to its nature, most for its fecundity, and the continuance and increase of its species; to which every species of animals is naturally prompt and inclined.

Thus admirable is the natural sagacity and instinct (*b*) of the irrational animals in the convenience and method of their habitations. And no less is it in the fabric of them. Their architectonic skill, exerted in the curiosity and dexterity of their works, and exceeding the skill of man to imitate; this, I say, deserves as much or more admiration and praise, than that of the most exquisite artist among men. For with what inimitable art (*i*) do these poor untaught

(*b*) It is a very odd story, (which I rather mention for the reader's diversion, than for its truth), which Dr Lud. de Beauport relates: 'Vir fide dignus narravit mihi, quod cum semel, animi gratia, nidum aviculæ ligno obturasset, seque occultasset, cupidus videndi, quid in tali occasione præstaret; illa cum frustra sæpius tentasset rostro illud auferre, casus admodum impatiens, abiit, et post aliquod temporis spatium reversa est, rostro gerens plantulam, qua obturamento applicata, paulo post, illud veluti telum eripuit tanta vi, ut dispersa impetu herbula, occasionem ipsi, ab avicula ejus virtutem discendi, præripuerit.' Cosmog. Divina, sect. 5. cap. 1. Had he told us what the plant was, we might have given better credit to this story.

(*i*) Of the subtilty of birds in nidification, see Plin. Nat. Hist. l. 10. c. 33.

creatures lay a parcel of rude and ugly sticks and straws, moss and dirt together, and form them into commodious nests! With what curiosity do they line them within, wind and place every hair, feather, or lock of wool, to guard the tender bodies of themselves, and their young, and to keep them warm! And with what art and craft do many of them thatch over, and coat their nests without, to doge and deceive the eye of spectators, as well as to guard and fence against the injuries of weather (*k*)! With what prodigious subtilty do some foreign birds (*l*) not only plat and weave the fibrous parts of vegetables together, and curiously tunnel them, and commodiously form them into nests, but also artificially suspend them on the tender twigs of trees, to keep them out of the reach of rapacious animals!

(*k*) Among many instances that might be given of this subtilty of birds, and other creatures, that of the long-tailed titmouse deserves observation, who, with great art, builds her nest with mosses, hair, and the webs of spiders, cast out from them when they take their flight; see book viii. chap. 5. note (*c*), with which the other materials are strongly tied together. Having neatly built, and covered her nest with these materials without, she thatcheth it on the top with the '*muscus arboreus ramosus*,' or such like broad, whitish moss, to keep out rain, and to dodge the spectator's eye; and within she lineth it with a great number of soft feathers, so many, that I confess I could not but admire how so small a room could hold them, especially that they could be laid so close and handsomely together, to afford sufficient room for a bird with so long a tail, and so numerous an issue as this bird commonly hath, which Mr Ray saith, (*Synops. Method. Avium*, p. 74.) '*Ova inter omnes aviculas numerosissima ponit.*' See more of the nest of this bird, from Aldrovand. in Willugh. Ornith. p. 243.

(*l*) The nest of the guira tangeima, the *isterus minor*, and the jupujuba, or whatever other name the American hang-nests may be called by, are of this kind. Of which see Willughby's Ornith. lib. 2. cap. 5. sect. 12, 13. Also Dr Grew's Musaeum Reg. Soc. part 1. sect. 4. cap. 4. These nests I have divers times seen, particularly in great perfection in our R. S. repository, and in the noble and well furnished Musaeum of my often commended friend, Sir Hans Sloane; and at the same time I could not but admire at the neat mechanism of them, and the sagacity of the bird, in hanging them on the twigs of trees, to secure their eggs and young from the apes.

And so for insects, those little, weak, those tender creatures; yet, what admirable artists are they in this business of nidification! With what great diligence doth the little bee gather its combs from various trees (*m*) and flowers, the wasp from solid timber (*n*)! And with what prodigious geometrical subtilty do those little animals work their deep hexagonal cells, the only proper figure that the best mathematician could chuse for such a combination of houses (*o*)! With what accuracy do other insects perforate the earth (*p*), wood, yea, stone itself (*q*)! For which service, the complete apparatus of their mouths (*r*), and feet (*s*), deserves particular obser-

(*m*) I mention trees, because I have seen bees gather the gum of fir-trees, which at the same time gave me the pleasure of seeing their way of loading their thighs therewith, performed with great art and dexterity.

(*n*) Wasps, at their first coming, may be observed to frequent posts, boards, and other wood that is dry and sound; but never any that is rotten. These they may be heard to scrape and gnaw; and what they so gnaw off, they heap close together between their chin and fore legs, until they have gotten enough for a burden, which they then carry away in their mouths, and make their cells with.

(*o*) Circular cells would have been the most capacious; but this would by no means have been a convenient figure, by reason much of the room would have been taken up by vacancies between the circles; therefore it was necessary to make use of some of the rectilinear figures. Among which only three could be of use; of which Pappus Alexandrinus thus discourseth: 'Cum igitur tres figurae sunt, quae per seipsas locum circa idem punctum consistentem replere possunt, triangulum, scil. quadratum, et hexagonum, apes illam, quae ex pluribus angulis constat, sapienter elegerunt, utpote suspicantes eam plus mellis capere quam utramvis reliquarum. At apes quidem illud tantum quod ipsis utile est cognoscant, viz. hexagonum quadrato et triangulo esse majus, et plus mellis capere posse; nimirum aequali materia in constructionem uniuscujusque consumpta. Nos vero qui plus sapientiae quam apes habere profitemur, aliquid etiam magis insigne investigabimus.' Collect. Matth. l. 5.

(*p*) See before note (*c*), p. 232.

(*q*) See chap. II. note (*v*), p. 201.

(*r*) See chap. II. note (*w*), p. 201.

(*s*) Among many examples, the legs and feet of the mole-cricket (*gryllotalpa*) are very remarkable. The fore-legs are very brawny and strong; and the feet armed each with four flat strong

vation, as hath been, and will be hereafter observed. And further yet; with what care and neatness do most of those little sagacious animals line those their houses within, and seal them up, and fence them without (*s*)! How artificially will others fold up the leaves of trees and plants (*t*); others house themselves in sticks and straws; others glue light and floating bodies together (*u*), and by that artifice make themselves

claws, together with a small lamina, with two larger claws, and a third with two little claws: which lamina is jointed to the bottom of the foot, to be extended, to make the foot wider, or withdraw within the foot. These feet are placed to scratch somewhat side-ways, as well as downward, after the manner of moles feet; and they are very like them also in figure.

Somewhat of this nature, Swammerdam observes of the worms of the ephemeron. 'To this purpose [to dig their cells] the wise Creator hath furnished them, saith he, with fit members. For, besides that their two fore-legs are formed somewhat like those of the ordinary moles, or gryllotalpa; he hath also furnished them with two toothy cheeks, somewhat like the sheers of lobsters, which serve them more readily to bore the clay.' Swammerdam's Ephem. Vit. published by Dr Tyson, chap. 3.

(*s*) See the before-cited note (*c*), p. 232.

(*t*) They are for the most part, some of the phalaenae-tribe, which inhabit the tunnelled, convolved leaves, that we meet with on vegetables in the spring and summer. And it is a somewhat wonderful artifice, how so small and weak a creature, as one of these newly-hatched maggots (for doubtless it is they, not the parent-animal, because she emits no web, nor hath any textrine art) can be able to convolve the stubborn leaf, and then bind it in that neat round form, with the thread or web it weaves from its own body; with which it commonly lines the convolved leaf, and stops up the two ends, to prevent its own falling out, and earwigs, and other noxious animals, getting in.

(*u*) The several sorts of phryganea, or cadews, in their nymphe, or maggot-state, thus house themselves; one sort in straws, called from thence straw-worms; others in two or more sticks, laid parallel to one another, creeping at the bottom of brooks; others with a small bundle of pieces of rushes, duck-weed, sticks, etc. glued together, therewith they float on the top, and crawl themselves therein about the waters, with the help of their feet: both these are called cod-bait. Divers other sorts there are, which the reader may see a summary of, from Mr Willughby, in *Raii Method. Insect.* p. 12. together with a good, though very brief description of the papilionaceous fly, that comes from the cod-bait cadew. It is a notable architectonic faculty, which all the variety of these animals have, to gather such bodies as are

floating houses in the waters, to transport themselves at pleasure after their food, or other necessary occasions of life ! And for a close, let us take the scriptural instance of the spider, Prov. xxx. 28. which is one of the four little things, which, ver. 24. Agur says, is exceeding wise : ‘ The spider taketh hold with her hands, and is in kings palaces (v).’ I will not dis-

fittest for their purpose, and then to glue them together ; some to be heavier than water, that the animal may remain at the bottom, where its food is ; (for which purpose they use stones, together with sticks, rushes, etc.) and some to be lighter than water, to float on the top, and gather its food from thence. These little houses look coarse, and shew no great artifice outwardly ; but are well tunnelled, and made within with a hard tough paste ; into which the hinder part of the maggot is so fixed, that it can draw its cell after it any where, without danger of leaving it behind ; as also thrust its body out, to reach what it wanteth ; or withdraw it into its cell, to guard it against harms.

(v) Having mentioned the spider, I shall take this occasion, although it be out of the way, to give an instance of the poison of some of them. Scaliger, Exerc. 186. relates, ‘ That in Gascony, his country, there are spiders of that virulency, that if a man trades upon them, to crush them, their poison will pass through the very soles of his shoe.’ Boyl. Subtil. of Effluv. c. 4.

Mr Leewenhoeck put a frog and a spider together into a glass, and having made the spider sting the frog divers times, the frog died in about an hour’s time. Phil. Transf. No. 272.

In the same Transaction, is a curious account of the manner how spiders lay, and guard their eggs, viz. they emit them not out of the hindmost part of the body, but under the upper part of her belly, near the hind legs, etc. Also there is an account of the parts from which they emit their webs, and divers other things worth observation, with cuts illustrating the whole.

But in Phil. Transf. No. 22. Dr. Nath. Fairfax, from S. Redi, and his own observations, thinks spiders not venomous ; several persons, as well as birds, swallowing them without hurt : which I myself have known in a person of learning, who was advised to take them medicinally at first, and would at any time swallow them, affirming them to be sweet, and well-tasted : and not only innocuous, but they are very salutiferous too, in some of the most stubborn diseases, if the pleasant story in Mouffet be true, of a rich London matron, cured of a desperate tympany, by a certain debauchee, that hearing of her case, and that she was given over by the doctors, went to her pretending to be a physician, and confidently affirming he would cure her ; which she being willing to believe, agrees with him for so much money, one half to be paid down, the other upon cure. Upon which he gives her a spider, promising her cure in three days. Whereupon (not

pute the truth of our English translation of this text; but supposing the animal mentioned to be that which is meant, it is manifest that the art of that species of creatures, in spinning their various webs, and the furniture their bodies afford to that purpose, are an excellent instinct and provision of nature, setting forth its glorious Author.

And now from this short and transient view of the architectonic faculty of animals, especially the irrationals; we may easily perceive some superior and wise Being was certainly concerned in their creation or original. For, how is it possible that an irrational creature should, with ordinary and coarse, or indeed any materials, be ever able to perform such works, as exceed even the imitation of a rational creature! How could the bodies of many of them, particularly the last mentioned, be furnished with architectivè materials! How could they ever discover them to be in their bodies, or know what use to make of them! We must therefore necessarily conclude, that the irrationals either have reason and judgment, not only glimmerings thereof, but some of its superior acts, as wisdom and foresight, discretion, art, and care; or else, that they are only passive in the case, and act by instinct, or by the reason of some superior Being imprinted in their nature, or some way or other, be it how it will, congenial with them. That they are rational, or excel man in art and wisdom, none surely will be so foolish as to say: and therefore we must conclude, that those excellent

doubting but that he had poisoned her, and fearing he might be called to account for it) he gets out of town as fast as he could. But instead of being poisoned, she soon recovered. After some months, the quack gets privately to town, when he thought the bustle might be over; and enquiring how his patient did, was informed of her cure; and thereupon visiting her, and making an excuse for his absence, he received his pay with great applause and thanks. *Mouff. Insect. l. 2. c. 15.*

Having said so much of spiders, I might here add their flight; but of this, see book viii. chap. 4. note (c).

ends they pursue, and that admirable art they exert, is none of their own, but owing to that infinitely-wise and excellent Being, of whom it may be said, with reference to the irrational, as well as rational creatures, as it is, Prov. ii. 6. 'The Lord giveth wisdom; out of his mouth cometh knowledge and understanding.'

CHAP. XIV.

Of Animals SELF-PRESERVATION.

HAVING thus considered the food, clothing, and houses of animals; let us in this chapter take a glance of another excellent provision the wise Creator hath made for the good of the animal world; and that is, the methods which all animals naturally take for their self-preservation and safety. And here it is remarkable, as in the cases before, that man, who is endowed with reason, is born without armature, and is destitute of many powers, which irrational creatures have in a much higher degree than he, by reason he can make himself arms to defend himself, can contrive methods for his own guard and safety, can many ways annoy his enemy, and flave off the harms of noxious creatures.

But for others, who are destitute of this super-eminent faculty; they are some way or other provided with sufficient guard (*a*), proportionate to their place of abode, the dangers they are like to incur there (*b*);

(*a*) 'Calent in hoc cuncta animalia, sciuntque non sua modo commoda, verum et hostium adversa; norunt sua tela, norunt occasiones, partesque dissidentium imbelles. In ventre mollis est tenuisque cutis crocodilo: ideoque se, ut territi, mergent delphini, subeuntesque alvum illa secant spina.' Plin. Nat. Hist. l. 8. c. 25.

(*b*) 'Omnibus aptum est corpus animae moribus et facultatibus: equo fortibus ungulis et juba est ornatum (etenim velox et superbum et generosum est animal). Leoni, autem, utpote animoso et feroci, dentibus et unguibus validum. Ita autem et tauro et apro; illi enim cornua, huic exerti dentes.—Cervo

and, in a word, to their greatest occasions and need of security. Accordingly, some are sufficiently guarded against all common dangers, by their natural clothing; by their armature of shells, or such like hard, and impregnable covering of their body (*c*). Others destitute of this guard, are armed, some with horns (*d*), some with sharp quills and prickles (*e*), some with

‘ autem et lepori, timida enim sunt animalia, velox corpus, sed inermis. Timidis enim velocitas, arma audacibus conveniebant — Homini autem, sapiens enim est —, manus dedit, instrumentum ad omnes artes necessarium, paci non minus quam bello idoneum. Non igitur indiguit cornu sibi innato, cum meliora cornibus arma manibus, quodcumque volet, possit accipere: etenim ensis et hasta majora sunt arma, et ad incidendum promptiora — Neque cornu, neque ungulae quicquam nisi cominus agere possunt; hominum vero arma eminus juxta ac cominus agunt: telum quidem et sagitta magis quam cornua. — Non igitur est nudus, neque inermis — sed ipsi est thorax ferreus, quodcumque libet, omnibus coriis difficiliter sauciato organum. — Nec thorax solum, sed et domus, et murus, et turris,’ etc. Galen. de usu Part. l. 1. c. 2.

(*c*) Shells deserve a place in this survey, upon the account of their great variety; the curious and uncouth make of some, and the beautiful colours, and pretty ornaments of others; but it would be endless to descend to particulars. Omitting others, I shall therefore only take notice of the tortoise-shell, by reason a great deal of dexterity appears, even in the simplicity of that animal’s skeleton. For, besides that the shell is a stout guard to the body, and affords a safe retreat to the head, legs, and tail, which it withdraws within the shell upon any danger; besides this, I say, the shell supplieth the place of all the bones in the body, except those of the extreme parts, the head and neck, and the four legs and tail. So that at first sight, it is somewhat surprising to see a complete skeleton consisting of so small a number of bones, and they abundantly sufficient for the creature’s use.

(*d*) Dente timentur apri: defendunt cornua tauros:

Imbelles Damae quid nisi præda sumus?

Martial. l. 13. Epigr. 94

(*e*) The hedge-hog being an helpless, slow, and patient animal, is accordingly guarded with prickles, and a power of rolling itself up in them. ‘ Clavis terebrari sibi pedes, et discindi viscera patientissime ferebat, omnes cultri ictus sine gemitu plusquam Spartana nobilitate corcoquens. Borrichius in Blas. de Echino. Panniculum carnosum amplexabatur musculus pene circularis, admirandae fabricae, lacinias suas ad pedes, caudam, caput, varie exporrigens, cujus ministerio echinus se ad arbitrium in orbem contrahit.’ Act. Dan. in Blasio.

Ille licet digitos testudine pungat acuta,

Cortice deposito mollis echinus erit. Mart. l. 13. Epig. 86

claws, some with stings (*f*); some can shift and change their colours (*g*); some can make their

(*f*) The sting of a wasp, or bee, etc. is so pretty a piece of work, that it is worth taking notice of, so far as I have not found others to have spoken of it. Others have observed the sting to be an hollow tube, with a bag of sharp penetrating juices, its poison, joined to the end of it, within the body of the wasp, which is, in stinging, injected into the flesh through the tube. But there are, besides this, two small, sharp, bearded spears, lying within this tube, or sting, as in a sheath. In a wasp's sting, I counted eight beards on the side of each spear, somewhat like the beards of fish-hooks. These spears in the sting, or sheath, lie one with its point a little before that of the other; as is represented in Fig. 21. to be ready, I conceive, to be first darted into the flesh; which being once fixed, by means of its foremost beard, the other then strikes in too, and so they alternately pierce deeper and deeper, their beards taking more and more hold in the flesh; after which the sheath or sting follows, to convey the poison into the wound. Which, that it may pierce the better, it is drawn into a point, with a small slit a little below that point, for the two spears to come out at. By means of this pretty mechanism in the sting, it is, that the sting, when out of the body, and parted from it, is able to pierce and sting us: and by means of the beards being lodged deep in the flesh, it comes to pass that bees leave their stings behind them, when they are disturbed, before they have time to withdraw their spears into their scabbard. In Fig. 21. is represented the two spears as they lie in the sting. In Fig. 22. the two spears are represented when squeezed out of the sting, or the scabbard; in which latter, Fig. Acb, is the sting, cd, and be, the two bearded spears thrust out.

(*g*) Theameleon is sufficiently famed on this account. Besides which, Pliny tells us of a beast as big as an ox, called the tarrandus, that when he pleaseth, assumes the colour of an ass, and 'Colorem omnium fruticum, arborum, florum, locorumque' redit, in quibus latet metuens, ideoque raro capitur.' Plin. l. 8. c. 34.

How true this is, there may be some reason to doubt; but if any truth be in the story, it may be from the animal's chusing such company, or places, as are agreeable to its colour: as I have seen in divers caterpillars, and other insects, who, I believe, were not able to change their colour, from one colour to another; yet I have constantly observed, do fix themselves to such things as are of the same colour; by which means they dodge the spectator's eye. Thus the caterpillar that feeds on elder, I have more than once seen, so cunningly adhering to the small branches of the same colour, that it might be easily mistaken for a small stick, even by a careful view. So a large green caterpillar, that feeds on buckthorn, and divers others. To which I may add,

escape by the help of their wings, and others by the swiftness of their feet; some can screen themselves by diving in the waters, others by tinging and disordering the waters (*h*), can make their escape; and some can guard their bodies even in the very flames, by the ejection of the juice of their bodies (*i*); and some by their accurate smell, sight, or hearing, can foresee dangers (*k*); others, by their natural craft, can prevent or escape them (*l*); others by their uncouth noise (*m*); by the horrid aspect, and ugly gesticulations of their body (*n*); and some even by the

the prodigious sagacity of the ichneumon flies, that make the kermes, for of that tribe all the kermes I ever saw were; how artificially they not only inclose their eggs within that gummy skin, or shell, but also so well humour the colour of the wood they adhere to, by various streaks and colours, that it is not easy to distinguish them from the wood itself.

(*h*) 'Contra metum et vim, suis se armis quaeque defendit. Cornibus tauri, apri dentibus, morsu leones, aliae fuga se, aliae occultatione tutantur: atramenti effusione sepiae, torpore torpedines. Multae etiam insectantes odoris intolerabili foeditate, depellunt.' Cic. de Nat. Deor. l. 2. c. 50.

(*i*) A knight, called Corvini, at Rome, cast a salamander into the fire, which presently swelled, and then vomited store of thick slimy matter, which put out the coals; to which the salamander presently retired, putting them out again in the same manner, as soon as they re-kindled, and by this means saved itself from the force of the fire, for the space of two hours; after which it lived nine months. Vide Phil. Trans. No. 21. in Lowth. Abridg. Vol. 2. p. 816.

(*k*) Pliny gives an instance in each, l. 10. c. 69. 'Aquilae clarius cernunt [quam homines]; vultures sagacius odorantur, liquidius audiunt talpae obrutae terra, tam denso atque surdo naturae elemento.'

(*l*) The doublings of the hare, before she goes to form, thereby to dodge and deceive the dogs, although a vulgar observation, is a notable instinct for an animal, less famed for cunning than the fox, and some others.

(*m*) It is natural for many quadrupeds, birds, and serpents, not only to put on a torvous angry aspect, when in danger, but also to snarl, hiss, or by some other noise deter their adversary.

(*n*) The iynx, or wryneck, although a bird of very beautiful feathers, and consequently far enough off from being any way terrible; yet, being in danger, hath such odd contortions of its neck, and motions of its head, that I remember have scared me, when I was a boy, from taking their nests, or touching the bird,

power of their excrements, and their stink (*o*), can annoy their enemy, and secure themselves; and against some (*p*), the divine providence itself hath provided a guard.

By such shifts and means as these, a sufficient guard is ministered to every species of animals, in its proper respective place; abundantly enough to secure the species from destruction, and to keep up that balance, which, I have formerly shewed, is in the world, among every, and all the species of animals; but yet not enough to secure individuals, from

daring no more to venture my hand into their holes, than if a serpent had lodged in it.

(*o*) 'Bonasus tuetur se calcibus et stercore, quod ab se quaternis passibus [trium jugerum longitudine. Plin. Nat. Hist. l. 8. c. 15.] ejaculatur, quod saepe comburit adeo ut deglabrentur eanes.' Ray's Synops. Quadr. p. 71.

'Camelus Peruvianus clama dictus neminem offendit, sed miro admodum ingenio se ab illata vindicat injuria, nimirum vomitu vel cibi, vel humeris in vexantem retrorsum cum impetu ejaculato, ob protensam colli longitudinem.' Id. ib. p. 146.

Tzquiepati, (Anglice Squunk, Praef. and one that I saw they called a Stonek), 'Cum quis eam insectatur, fundit cum ventris crepitu halitum foetidissimum: quin ipsa tota teterrimum exhalat odorem, et urina stercusque est foetidissimum, atque adeo pestilens, ut nihil sit reperire in nostro orbe, cui in hac re possit comparari: quo fit ut in periculo constituta, urinam et faeces ad 8 pluriumve passuum intervallum ejiciat, hoc modo se ab omnibus vindicans injuriis, ac vestes inficiens maculis luteis indelibilibus, et nunquam satis perspirante odore: alias innoxium animal eduleque, hac sola ratione horrendissimum.' Id. ib. p. 182.

'Si accipiter ardeam in sublimi molestat, stercore immisso in pennas ejus, eas putrescere facit: uti Solinus scribit de Bonaso, etc. Ita et lupus urinam spargit in persequentem.' Ol. Mag. Hist. l. 19. c. 14.

(*p*) Thus against the crocodile, which can catch its prey only before it, not on one side. So the shark, of which take my often commended friend Sir Hans Sloane's observation; 'It has this peculiar to it, with some others of its own tribe, that the mouth is in its under part, so that it must turn the belly upwards to prey. And was it not for that time it is in turning, in which the pursued fishes escape, there would be nothing that could avoid it; for it is very quick in swimming, and hath a vast strength, with the largest swallow of any fish, and is very devouring.' Sloane's Voy. to Jamacia, p. 23.

becoming a prey to man, or to other creatures, as their necessities of life require. To which purpose, the natural sagacity and craft of the one intrapping (q), and captivating, being in some measure equivalent to that of the other in evading, is as excellent a means for the maintaining the one, as preserving the other; and, if well considered, argues the contrivance of the infinitely wise Creator and Preserver of the world.

C H A P. XV.

Of the GENERATION of Animals.

TH E R E remains now only one thing more of the ten things in common to animals, and that is what relates to their generation (a), and con-

(q) See chap. XI. note (ccc), p. 212.

(a) Spontaneous generation is a doctrine so generally exploded, that I shall not undertake the disproof of it. It is evident, that all animals, yea, vegetables too, owe their production to parent animals and vegetables; that I have often admired at the sloth and prejudices of the ancient philosophers, in so easily taking upon trust the Aristotelian, or rather the Egyptian doctrine of equivocal generation; that when they saw flies, frogs, and lice, for instance, to be male and female, and accordingly to ingender, lay eggs, etc. they could ever imagine any of these creatures should be spontaneously produced, especially in so romantic a manner, as in the clouds; as they particularly thought frogs were, and that they dropped down in showers of rain. For an answer to this case of frogs, I shall refer to a relation of my own, which my late most ingenious and learned friend, the great Mr Ray, requested of me, and was pleased to publish in his last edition of his *Wisdom of God manifested*, etc. p. 365.

But some will yet assert the raining of frogs; among which the curious Dr Plot is somewhat of this opinion; telling us of frogs, found on the leads of the lord Aston's gate-house, at Tixal in Staffordshire, which he thinks by some such means came there; as also on the bowling-green, frequently after a shower of rain. Plot's *Hist. Staff.* c. I. sect. 47.

But we may take a judgement of this, and an hundred such like reports, to be met with in considerable authors, from other the like reports that have been better inquired into, In a fear-

city in Silesia, a mighty rumour was spread of its raining millet-seed: but the matter being inquired into, it was found to be only the seeds of the ivy-leaved speedwell, or small henbit, growing in the place in great plenty. Eph. Germ. An. 3. Obs. 49. So in the Archipelago, it was thought ashes were rained, ships being covered therewith at a hundred leagues distance: but in a probability, it was from an eruption of Vesuvius, that then happened. About Warminster in Wilts, it was reported it rained wheat; but a curious observer, Mr Cole, found it to be only ivy-berries, blown thither in a considerable quantity by a tempest. In the year 1696, at Cranstead near Worthan in Kent, a pasture-field was overspread with little young whittings, supposed to fall from the clouds in a tempest of thunder and rain; but doubtless they were brought thither with waters from the sea by the tempest. See the before commended Mr Low. Abridg. Phil. Transf. vol. ii. p. 143, 144.

Neither needeth it seem strange, that ashes, ivy-berries, small fishes, or young frogs, (which yet may have some other conveyance), should be thus transported by tempestuous winds, considering to what distance, and in what quantities, the sea-waters were carried by the great storm, Nov. 26, 1703, of which an ingenious friend sent me these accounts from Lewes in Sussex, viz. That a physician travelling soon after the storm, to Titchhurst, twenty miles from the sea, as he rode along plucked some tops of hedges, and chewing them, found them salt: that some grapes hanging on the vines at Lewes, were so too: that Mr Williamson, rector of Ripe, found the twigs in his garden salt the Monday after the storm; and others observed the same a week after. That the grass of the downs about Lewes, was so salt, that the sheep would not feed till hunger compelled them: and that the miller of Berwick, three miles from the sea, attempting with his man to secure his mill, were so washed with flashes of sea-water, like the breakings of waves against the rocks, that they were almost strangled therewith, and forced to give over their attempt.

I called the doctrine of equivocal generation, an Egyptian doctrine, because probably it had its rise in Egypt, to solve the hypothesis of the production of men, and other animals, out of the earth, by the help of the sun's heat. To prove which, the Egyptians, as Diod. Sicul. saith, produceth this observation, That about Thebes, when the earth is moistened by the Nile, by the intense heat of the sun, an innumerable number of mice do spring out. From whence he infers, that all kinds of animals, might as well at first come likewise out of the earth. And from these the learned bishop Stillingfleet thinks other writers, as Ovid, Mela, Pliny, etc. have, without examining its truth, taken up the same hypothesis. Vide Stillingfleet's Orig. Sac. part 2. book i. chap. 1.

The before-commended Dr Harris, from the observations of Dr Harvey, S. Malpighi, Dr De Graaf, and Mr Leeuwenhoeck, infers three things concerning generation; as highly probable.

servation of their species (*b*), by that means. It would not be seemly to advance far in this admirable work of God; neither shall I at all insist upon that of man, for the same reason. And as for the irrationals (*c*), I shall confine myself to these five matters.

I. Their natural sagacity in chusing the fittest places to reposit their eggs and young.

II. The fittest times and seasons they make use of for their generation.

III. The due and stated number of their young.

IV. Their diligence and earnest concern in their breeding up.

V. Their faculty of feeding them; and their art and sagacity exerted therein.

I. The natural sagacity of irrational animals, in chusing the fittest places to reposit their eggs and young. Of this I have given larger hints already than I needed to have done, when I spake of the architecture (*d*) of animals, intending then to have wholly passed by this business of generation: I shall therefore now only superadd a few other instances, the more to illustrate this matter.

It hath been already shewn, and will hereafter (*e*)

1. 'That animals are ex animalculo. 2. That the animalcules are originally in semine marium, et non in foeminis. 3. That they can never come forward, or be formed into animals of the respective kind, without the ova in foeminis.' His proofs and illustrations, see under the word Generations, in his *Lex. Tech.* v. 2.

(*b*) 'At certe natura, si fieri potuisset, maxime optasset suum opificium esse immortale: quod cum per materiam non liceret (nam quod—ex carne est compositum, incorruptibile esse non potest) subsidium quod potuit ipsi ad immortalitatem est fabricata, sapientis cujusdam urbis conditoris exemplo, etc. Nam mirabilem quandam rationem invenit, quomodo in demortui animalis malis locum, novum aliud sufficiat.' *Gal. de Usu Part.* l. 14. c. 22.

(*c*) 'Animantia bruta obstetricibus non indigent in edendo partu, cum indita naturae vi umbilicus seipsum occludat.' Ol. Rudbeck, in *Blasii Anat. Felis*.

(*d*) Chap. 13.

(*e*) Book viii. chap. 6.

farther appear, that the places in which the several species of animals lay up their eggs, and young, are the best for that purpose; waters (*f*) for one; flesh for another; holes in wood (*g*), earth, or stone (*h*), for others; and nests for others; and we shall find, that so ardent is the propensity of all animals, even of the meanest insects, to get a fit place for the propagation of their young, that, as will hereafter appear, there is scarce any thing that escapeth the inquest of those little subtle creatures. But besides all this, there are two or three things more observable, which plainly argue the instinct of some superior rational being. As,

1. The complete and neat order which many creatures observe in laying up their seed, or eggs, in proper repositories: of which I shall speak in another place (*i*).

2. The suitable apparatus in every creature's body, for the laying up its eggs, seed, or young, in their

(*f*) The ephemeron, as it is an unusual and special instance of the brevity of life, so I take it to be a wonderful instance of the special care and providence of God, in the conservation of the species of that animal. For, 1. As an animal, whose life is determined in about five or six hours time, (*viz.* from about six in the evening, till about eleven o' clock at night), needs no food; so neither doth the ephemeron eat, after it is become a fly. 2. As to its generation; in those five hours of its life, it performs that, and all other necessary offices of life: for in the beginning of its life, it sheds its coat; and that being done, and the poor little animal thereby rendered light and agile, it spends the rest of its short time in frisking over the waters, and at the same time the female droppeth her eggs on the waters, and the male his sperm on them, to impregnate them. These eggs are spread about by the waters; descend to the bottom by their own gravity; and are hatched by the warmth of the sun, into little worms, which make themselves cases in the clay, and feed on the same without any need of parental care. Vide *Ephem vita*, translated by Dr Tyson, from Swammerdam. See also book viii. chap. 6. note (*r*).

(*g*) See chap. 13. note (*c*) p. 232. and book viii. chap. 6.

(*h*) The worms in chap. 11. note (*v*) p. 201. breed in the holes they gnaw in stone, as is manifest from their eggs found therein.

(*i*) See book viii. chap. 6. note (*g*).

proper place. It would be as endless as needfuls to name all particulars, and therefore an instance or two of the insect-tribe may serve for a specimen in this place, till I come to other particulars. Thus insects, who have neither feet adapted to scratch, nor noses to dig, nor can make artificial nests to lay up their young; yet what abundant amends is there made them, in the power they have either to extend the abdomen (*k*), and thereby reach the commodious

(*k*) Many, if not most flies, especially those of the flesh fly-kind, have a faculty of extending their uropygia, and thereby are enabled to thrust their eggs into convenient holes, and receptacles for their young, in flesh, and whatever else they fly-blow; but none more remarkable than the horse-fly, called by Pennius in Mouffet, (p. 62) *Σκολύρος*, etc. *Curvicauda*, and the whame or burrel-fly, which is vexatious to horses in summer, not by stinging them, but only by their bombylious noise, or tickling them, in sticking their nits, or eggs on the hair; which they do in a very dexterous manner, by thrusting out their uropygia, bending them up, and by gentle, slight touches, sticking the eggs to the hair of the legs, shoulders, and necks, commonly of horses; so that horses which go abroad, and are seldom dressed, are somewhat discoloured by the numerous nits adhering to their hair.

Having mentioned so much of the generation of this insect, although it be a little out of the way, I hope I shall be excused for taking notice of the long-tailed maggot, which is the product of these nits or eggs, called by Dr Plot, *eruca glabra*, [or rather *eruca scabra*, it should be] *caudata aquatico-arborea*, it being found by him in the water of an hollow-tree; but I have found it in ditches, saw-pits, holes of water in the high-way, and such like places, where the waters are most still and foul. This maggot I mention, as being a singular and remarkable work of God, not so much for its being so utterly unlike as it is to its parent beetle-like fly, as for the wise provision made for it by its long tail; which is so jointed at certain distances from the body, as that it can be withdrawn, or sheathed, one part within another, to what length the maggot pleaseth, so as to enable it to reach the bottom of very shallow, or deeper waters, as it hath occasion, for the gathering of food. At the end of this tapering is a ramification of fibrillae, or small hairs, representing, when spread, a star; with the help of which, spread out on the top of waters, it is enabled to hang, making, by that means, a small depression or concavity on the surface of the water. In the midst of this star, I imagine the maggot takes in air, there being a perforation, which, with a microscope, I could perceive to be open

places they could not otherwise come at; or else they have some aculeous part or instrument to terebrate, and make way for their eggs into the root (*l*), trunk (*m*), fruit (*n*), leaves (*o*), and the tender buds

and by the star to be guarded against the incurſion of the wa-
ter.

(*l*) The excrescences on the root of cabbages, turneps, and divers other plants, have always a maggot in them; but what the animal is that thus makes its way to the root under ground, whether ichneumon, phalaena, scarab, or scolopendra, I could never discover, being not able to bring them to any thing in boxes.

(*m*) I presume there are only of the ichneumon-fly-kind, that have their generation in the trunks of vegetables. In Malpighi de Gallis, Fig. 61. is a good cut of the gouty excrescences, or rather tumours, of the briar-stalk: from which proceeds a small black ichneumon fly, with red legs; black, smooth jointed antennae; pretty large thorax; and short, round belly, in the shape of an heart. It leapeth as a flea. The male, as in other insects, is lesser than the female, and very venereous, in spite of danger, getting upon the female, when they beat and tickle with their breeches and horns to excite them to a coit.

Another example of the generation in the trunks of vegetables, shall be from the papers of my often commended friend Mr Ray, which are in my hands, and that is an observation of the ingenious Dr Nathaniel Wood: 'I have, said he, lately observed many eggs in the common rush; one sort are little transparent eggs, in shape somewhat like a pear, or retort, lying within the skin, upon, or in the medulla, just against a brownish spot on the outside of the rush; which is apparently the creatrix of the wound made by the fly, when she puts her eggs there. Another kind is much longer, and not so transparent, of a long oval, or rather cylindrical form; six, eight, or more, lie commonly together, across the rush, parallel to each other, like the teeth of a comb, and are as long as the breadth of the rush.' Letter from Kilkenny in Ireland, April the 28, 1697.

(*n*) See book viii. chap. 6. note (*d*).

(*o*) I have, in chap. 13. note (*f*), p. 238. and book viii. chap. 6. note (*e*) and (*f*), taken notice of the nidification and generation of some insects, on the leaves of vegetables, and shall therefore, for the illustration of this place, chuse an uncommon example out of the scarab-kind, (the generation of which tribe hath not been as yet mentioned), and that is, of a small scarab bred in the very tips of elm-leaves. These leaves, in summer, may be observed to be, many of them, dry and dead, as also turgid; in which lieth a dirty, whitish, rough maggot. From which proceeds a beetle of the smallest kind, of a light, ashesel colour, that leapeth like a grasshopper, although its legs

of vegetables (*p*), or some other such curious and secure method they are never destitute of. To which we may add,

3. The natural poison (*q*), or what can I call it? which many, or most of the creatures, last intended, have, to cause the germination of such balls, cases, and other commodious repositories, as are an admirable lodgement to the eggs and young; that particularly assist in the incubation and hatching the young, and then afford them sufficient food and nourishment in all their nympha-state, in which they need food; and are afterwards commodious houses and beds for them in their aurelia-state, till they are able to break prison, fly abroad, and shift for themselves. But this shall be taken notice of, when I come to treat of insects.

II. As irrational animals chuse the fittest place, so also the fittest times and seasons for their generation. Some indeed are indifferent to all times, but others make use of peculiar seasons (*r*). Those, for instance, whose provisions are ready at all seasons, or who are under the tuition of man, produce their young without any great regard to heat or cold, wet or dry,

are but short. Its eyes are blackish, elytra thin, and prettily furrowed, with many concavities in them; small club-headed antennae, and a long rostrum like a proboscis.

The same, or much like this, I have met with on tips of oaken and holly-leaves. How the scarab lays its eggs on the leaf, whether by terebrating the leaf, or whether the maggot, when hatched, doth it, I could never see. But with great dexterity it makes its way between the upper and under membranes of the leaf, feeding upon the parenchymous part thereof. Its head is slenderer and sharper than most of maggots, as if made on purpose for this work; but yet I have often wondered at their artifice, in so nicely separating the membranes of the elm-leaf, without breaking them, and endangering their own tumbling out of them, considering how thin, and very tender, the skins of that leaf particularly are.

(*p*) See book viii. chap. 6. note (*z*).

(*q*) See book viii. chap. 6. to note (*bb*), etc.

(*r*) Πολλά δὲ καὶ πρὸς ἐκτροφῆς τῶν τέκνων ὁτοχάζόμενα, ποῦνται τοῖς συνδυασμὸν ἐν τῇ ἀπαρτιζέσῃ ἄρρ. Arist. Hist. An. l. 5. c. 8. ubi plura.

summer or winter. But others, whose provisions are peculiar, and only to be met with at certain seasons of the year; or who, by their migration, and change of place, are tied up to certain seasons; these (as if endowed with a natural care and foresight of what shall happen) do accordingly lay, hatch, and nurse up their young in the most proper seasons of all the year for their purpose; as in spring, or summer, the times of plenty of provisions, the times of warmth for incubation, and the most proper seasons to breed up their young, till they are able to shift for themselves, and can range about for food, and seek places of retreat and safety, by flying long flights as well as their progenitors, and passing into far distant regions, which, when others fail, afford those helpless creatures the necessaries of life.

III. To the special seasons, I may add the peculiar numbers of young produced by the irrational creatures. Of which I have already taken some notice, when I spake of the balance of animals (*f*). Now, if there was not a great deal more than chance in this matter, even a wise government of the creation, it could never happen that every species of animals should be tied up to a certain rate and proportion of its increase; the most useful would not be the most fruitful, and the most pernicious produce the fewest young, as I have observed it commonly is. Neither would every species produce such a certain rate as it is only able to breed up; but all would be in a confused, huddled state. Instead of which, on the contrary, we find every thing in complete order; the balance of genera, species and individuals always proportionate and even; the balance of sexes the same; most creatures tied up to their due stint and number of young, without their own power and choice, and others (particularly of the winged (*s*) kind) produ-

(*f*) See chap. x.

(*s*) Mr Ray alledges good reason to conclude, that although

cing their due number at choice and pleasure ; some large numbers, but not more than they can cover, feed and foster ; others fewer, but as many as they can well nurse and breed up. Which minds me,

IV. Of the diligence and earnest concern which irrational animals have of the production and breeding up their young. And here I have already taken notice of their *στοργή*, or natural affection, and with what zeal they feed and defend their young. To which may be added these two things :

1. The wonderful instinct of incubation. It is utterly impossible, that ever unthinking, untaught animals should take to that only method of hatching their young, was it not implanted in their nature by the infinitely wise Creator. But so ardent is their desire, so unwearied is their patience, when they are engaged in that business, that they will abide their nests for several weeks, deny themselves the pleasures, and even the necessities of life ; some of them even starving themselves almost, rather than hazard their eggs to get food ; and others either performing the office by turns (*t*), or else the one kindly seeking out, and carrying food to the other (*u*), engaged in the of-

birds have not an exact power of numbering, yet, that they have of distinguishing many from few, and knowing when they come near to a certain number ; and that they have it in their power to lay many or few eggs. All which he manifesteth from hens, and other domestic fowls, laying many more eggs when they are withdrawn, than when not. Which holds in wild as well as domestic birds, as appears from Dr Lister's experiment in withdrawing a swallow's egg, which by that means laid nineteen eggs successively before she gave over. Vide Ray's Wisdom of God, etc. p. 137.

(*t*) 'Palumbæ incubat foemina post meridia in matutinum, caetero mas. Columbæ incubant ambo, interdiu mas, noctu foemina.' Plin. Nat. Hist. l. 10. c. 58.

(*u*) Of the common crow, Mr Willoughby saith, 'The females only sit, and that diligently, the males in the mean time bring them victuals ; as Aristotle saith. In most other birds, which pair together, the male and female sit by turns.' Ornithol. l. 2. sect. 1. c. 2. sect. 2. And I have observed the female-crows to be much fatter than the males, in the time of incubation ; by reason

fice of incubation. But of these matters in a more proper place (x).

2. When the young ones are produced, not only with what care do they feed and nurse them; but with what surprising courage do all or most creatures defend them! It is somewhat strange to see timid creatures (y), who at other times are cowardly, to be full of courage, and undaunted at that time; to see them furiously and boldly encounter their enemy, instead of flying from him; and expose themselves to every danger, rather than hazard and forsake their young.

With this earnest concern of the irrational animals for their young, we may join in the

V. And last place, their faculty and sagacity of feeding them. About which I shall take notice of three things:

1. The faculty of suckling the young is an excellent provision the Creator hath made for those helpless creatures. And here the agreeableness and suitability of that food to young creatures deserves particular observation; as also their delight in it, and desire and endeavours after it, even as soon as born (z), together with the willingness of all, even the most savage and fierce animals, to part with it,

the male, out of his conjugal affection, almost starves himself to supply the female with plenty.

(x) See book vii. chap. 4.

(y) 'Volucris natura novam quandam, pullos educandi, rationem excogitavit: ipsis enim praeceptum quandam amorem in ea quae procrearent, ingeneravit, quo impulsu bellum pro pullis cum ferocibus animalibus, quae ante declinarunt, intrepide suscipiunt, victumque ipsis convenientem suppeditant.' Galen de usu Part. l. 14. c. 4.

(z) 'In iis animantibus quae lacte aluntur, omnis fere cibus matrum lactescere incipit, eaque, quae paulo antenata sunt, sine magistro, duce natura, mammas appetunt, carumque ubertate saturantur. Atque ut intelligamus nihil horum esse fortuitum, et haec omnia esse providae, solertisque naturae, quae multiplices foetus procreant, ut fues, ut canes, his mammarum data est multitudo; quas easdem paucas habent eae bestiae, quae pauca gignunt.' Cic. de Nat. Deor. l. 2. c. 51. Consule quoque Galen de usu Part. l. 14. c. 4. et l. 15. c. 7.

and to administer it to their young, yea, to teach and institute them in the art of taking it.

And lastly, to name no more, the curious apparatus which is made for this service in the divers species of animals, by a due number of breasts, proportionable to the occasions of each animal, by curious glands in those breasts, to separate that nutritive juice, the milk, by arteries and veins to convey it to them, and proper rivulets and channels to convey it from them, with dugs and nipples, placed in the most convenient part of the body (*aa*) of each animal, to administer it to their young; all these things, I say, do manifestly proclaim the care and wisdom of the great Creator.

2. As for such animals as do in another manner breed up their young, by finding out food, and putting it in to their mouth, the provision made in them for this service, to strike, catch, to pouch and convey their prey and food to their young (*bb*), is very considerable. And so is also their sagacity in equally distributing it among them, that among many, all shall be duly, equally, and in good order, fed.

(*aa*) 'Animalia solidipeda et ruminantia, vel cornigera, inter
 • femora mammas habent, quorum foetus statim a partu pedibus
 • insistant, quod matres inter lactandum non decumbant ut equa,
 • asina, etc. Animalia digitata et multipara in medio ventre,
 • scil. spatio ab inguine ad pectus, in cuniculo usque ad jugulum,
 • duplicem mammarum seriem sortita sunt, quae omnia decum-
 • bentia ubera foetibus admovent, ut ursa, leaena, etc. Si vero
 • haec in solo inguine mammas gererent, propria cura inter de-
 • cumbendum foetus accessum ad mammas nonnihil praepedirent.
 • Mulieribus mammae binae sunt, ut et papillae, nimirum ut la-
 • tus lateri conformiter respondeat, et ut alternatim infans a latere
 • in latus inter sugendum transferatur, ne corpus ejus uni lateri
 • nimis assuescens quoquo modo incurvetur. Simia, homo sylve-
 • stris, etc. Blas. Anat. Animal. part. 1. c. 6. de cane ex Whar-
 • tono. See here what Pliny hath also, l. 11. c. 40.

In the elephant, the nipples are near the breast, by reason the old one is forced to suck herself, and by the help of her trunk conveys the milk into the mouth of her young. Vide Phil. Trans. No. 336.

(*bb*) For an exemplification, I might name many animals, particularly birds, whose parts are completely suited to this service.

3. There is yet another instinct remaining, of such animals as can neither administer suck to their young, neither lay them in places affording food, nor can convey and bring them food, but do with their eggs, lay up provisions for their future young. Somewhat of this is reported of some birds (*cc*); but I have myself, with pleasure, frequently seen some of the species of insects to carry ample provisions into their dry and barren cells, where they have sealed them carefully and cautiously up with their eggs, partly, it is like, for incubation-sake, and partly as an easy bed to lodge their young; but chiefly, for future provision for their young, in their nympha-state, when they stand in need of food (*dd*).

They are characteristics of rapacious birds, to have aduncous bills and talons to hold and tear; and strong brawny thighs to strike and carry their prey; as well as a sharp piercing sight to espy it afar off. *Raii Synopf. Method. Av. p. 1.* The pelican also might be here named, for its prodigious bag under its bill and throat; big enough to contain thirty pints. *Id. ibid. p. 122.* And, to name no more, the common heron hath its most remarkable parts adapted to this service; long legs for wading; and a long neck answerable thereto to reach prey; a wide, extensive throat to pouch it; long toes, with strong hooked talons, (one of which is remarkably serrate on the edge), the better to hold their prey; a long sharp bill to strike their prey; and serrate towards the point, with sharp hooked beards standing backward, to hold their prey fast when struck; and lastly, large, broad, concave wings (in appearance much too large, heavy, and cumbersome for so small a body, but) of greatest use to enable them to carry the greater load to their nests, at several miles distance; as I have seen them do from several miles beyond me, to a large heronry above three miles distant from me. In which I have seen plaice, and other fish, some inches long, lying under the high trees in which they build; and the curious and ingenious owner thereof, D'Acre Barret, Esq; hath seen a large eel conveyed by them, notwithstanding the great annoyance it gave them in their flight, by its twisting this way and that way about their bodies.

(*cc*) This is reported of the American ostrich mentioned by Acaette, in *Philos. Trans. No. 89.* Of which see book vii. chap. 4. note (*c*).

(*dd*) Hornets, wasps, and all the kinds of bees provide honey; and many of the pseudophecæ, and ichneumon wasps and flies, carry maggots, spiders, etc. into their nests; of which see above, chap. 13. note (*c*), p. 232.

C H A P. XVI.

The CONCLUSION.

THUS I have, as briefly as I well could, (and much more briefly than the matters deserved), dispatched the decalogue of things I proposed in common to the sensitive creatures. And now let us pause a little, and reflect. And upon the whole matter, what less can be concluded, than that there is a Being infinitely wise, potent, and kind, who is able to contrive and make this glorious scene of things, which I have thus given only a glance of ! For, what less than infinite could stock so vast a globe with such a noble set of animals ! all so contrived, as to minister to one another's help some way or other, and most of them serviceable to man peculiarly, the top of this lower world, and who was made, as it were, on purpose to observe, and survey and set forth the glory of the infinite Creator, manifested in his works ! Who ? what but the great GOD, could so admirably provide for the whole animal world, every thing serviceable to it, or that can be wished for, either to conserve its species, or to minister to the being or well-being of individuals ! Particularly, who could feed so spacious a world, who could please so large a number of palates, or suit so many palates to so great a variety of food, but the infinite Conservator of the world ! And who but the same great HE, could provide such commodious clothing for every animal ; such proper houses, nests, and habitations ; such suitable armature and weapons ; such subtilty, artifice, and sagacity, as every creature is more or less armed and furnished with, to fence off the injuries of the weather, to rescue itself from dangers, to preserve itself from the annoyances of its enemies ; and, in a word, to conserve itself, and its species ! What but

an infinite superintending Power could so equally balance the several species of animals, and conserve the numbers of the individuals of every species so even, as not to over or under-people the terraqueous globe! Who, but the infinite wise LORD of the world, could allot every creature its most suitable place to live in, the most suitable element to breathe, and move, and act in! And who, but HE, could make so admirable a set of organs, as those of respiration are, both in land and water animals! Who could contrive so curious a set of limbs, joints, bones, muscles, and nerves, to give to every animal the most commodious motion to its state and occasions! And, to name no more, what anatomist, mathematician, workman, yea, angel, could contrive and make so curious, so commodious, and every way so exquisite a set of senses, as the five senses of animals are; whose organs are so dexterously contrived, so conveniently placed in the body, so neatly adjusted, so firmly guarded, and so completely suited to every occasion, that they plainly set forth the agency of the infinite Creator and Conservator of the world!

So that here, upon a transient view of the animal world in general only, we have such a throng of glories, such an enravishing scene of things, as may excite us to admire, praise, and adore the infinitely wise, powerful, and kind CREATOR; to condemn all atheistical principles; and with holy David, Psalm xiv. 1. to conclude, that he is in good earnest a fool, that dares to say, 'There is no God,' when we are every where surrounded with such manifest characters, and plain demonstrations of that infinite Being.

But in the next book we shall still find greater tokens, if possible, when I come to take a view of animals in particular.

A
S U R V E Y
OF THE PARTICULAR
TRIBES OF ANIMALS.

IN the foregoing book, having taken a view of the things in common to animals, my business, in the next, will be to inspect the particular tribes, in order to give further manifestations of the infinite Creator's wisdom, power, and goodness towards the animal world.

BOOK V.
A SURVEY of MAN.

THE first genus of animals that I shall take notice of, shall be **MAN**, who may justly claim the precedence in our discourse, inasmuch as **GOD** hath given him the superiority in the animal world. Gen. i 26.
' And God said, Let us make man in our image,
' after our likeness; and let them have dominion
' over the fish of the sea, and over the fowl of the
' air, and over the cattle, and over all the earth,
' and over every creeping thing that creepeth upon
' the earth.'

And as to man, we have so excellent a piece of workmanship, such a microcosm, such an abridgement of the Creator's art in him, as is alone sufficient to demonstrate the being and attributes of God. Which will appear, by considering the soul and the body of man.

CHAP. I.

Of the SOUL of Man.

MY survey of man I shall begin with the soul of man, by reason it is his most noble part (a), the copy of the divine image in us (b), in which we have enough to fill us with admiration of the munificence, power, and wisdom of the infinite Creator (c), when we contemplate the noble faculties of this our superior part, the vast reach and compass of its understanding, the prodigious quickness and piercingness of its thought, the admirable subtilty of its invention, the commanding power of its wisdom, the great depth of its memory (d), and, in a word, its divine nature and operations.

(a) ' Jam vero animum ipsum, mentemque hominis, rationem, consilium, prudentiam, qui non divina cura perfecta esse perspicit, is his ipsis rebus mihi videtur carere.' Cic. de Nat. Deor. l. 2. c. 59.

(b) Sensum a coelesti demissum traximus arce,
Cujus egent prona, et terram spectantia : mundi
Principio indulsit communis conditor illis
Tantum animas ; nobis animum quoque.

Juv. Sat. xv. ver. 144

Et cum non aliter possent mortalia fingi,
Adjunxit geminas, illae cum corpore lapsae
Intercunt : haec sola manet, bustoque superstes
Evolat.

Claud. de 4 Consul. Hon.

(c) ' Nam si quis nulli sectae addictus, sed libera sententia rerum considerationem inierit, conspicatus in tanta carnum ac succorum colluvie tantam mentem habitare ; conspicatus item et cujusvis animalis constructionem (omnia enim declarant opificis sapientiam) mentis, quae homini inest, excellentiam intelliget, tum opus de partium utilitate, quod prius exiguum esse sibi videbatur, perfectissimae theologiae verum principium constituet : quae theologia multo est major atque praestantior tota medicina.' Galen de Usu Part. l. 17. c. 1.

(d) Among many examples that I could give of persons famous for memory, Seneca's account of himself may be one : Hanc [memoriam] aliquando in me floruisse, ut non tantum ad usum sufficeret, sed in miraculum usque procederet, non nego.

But I shall not dwell on this, though the superior part of man, because it is the least known. Only there are two things I cannot easily pass by, because they manifest the special concurrence and design of the infinitely wise Creator; as having a particular and necessary tendency to the management and good order of the world's affairs. The

I. Of which is the various genii, or inclinations of mens minds to this, and that, and the other business (*e*). We see how naturally men betake themselves to this and that employment: some delight most in learning and books, some in divinity, some in physic, anatomy, and botany, some in critical learning, and philology, some in mathematics, some in metaphysics, and deep researches; and some have their delight chiefly in mechanics, architecture, war, navigation, commerce, agriculture; and some have their inclinations lie even to the servile offices of the world, and an hundred things besides.

Now all this is an admirably wise, as well as most necessary provision, for the easy and sure transacting

' Nam et 2000 nominum recitata, quo ordine erant dicta, red-
' debam: et ab his qui ad audiendum preceptorem nostrum con-
' venerunt, singulos versus a singulis datos, cum plures quam 200
' efficerentur, ab ultimo incipiens usque ad primum recitabam.'
After which, mention is made of the great memory of *Latro Porcius*, (*charissime mihi sodalis*, *Seneca* calls him) who retained in his memory all the declamations he had ever spoken, and never had his memory fail him, not so much as in one single word. Also, he takes notice of *Cyneas*, ambassador to the Romans, from king *Pyrrhus*, who in one day had so well learned the names of his spectators, that ' *postero die novus homo et senatum, et om-*
' *nem urbanam circumfusam senatu plebem, nominibus suis per-*
' *salutavit.*' *Senec. Controvers. l. 1. init.* Vide quoque *Plin.*
l. 7. c. 24. where he also adds other examples, viz. ' *Cyrus rex*
' *omnibus in exercitu suo militibus nomina reddidit; L. Scipio*
' *populo Rom. Mithridates 22 gentium rex, totidem linguis jura*
' *dedit, pro concione singulas sine interprete affatus, Charmidas,*
' *seu potius Carneades,—quae quis exegerat volumina in biblio-*
' *thecis, legentis modo representavit.'*

(*e*) *Diversis etenim gaudet natura ministris,
Ut fieri diversa queant ornantia terras.*

Nec patitur cunctos ad eandem currere metam,

the world's affairs; to answer every end and occasion of man, yea, to make man helpful to the poor helpless beasts as far as his help is needful to them; and all, without any great trouble, fatigue, or great inconvenience to man; rather as a pleasure and diversion to him. For so far it is from being a toil, that the greatest labours (*f*), cares, yea, and dangers too, become pleasant to him who is pursuing his genius, and whose ardour of inclination eggs him forward, and buoys him up under all opposition, and carrieth him through every obstacle, to the end of his designs and desires.

II. The next is, the Inventive power of the soul (*g*). Under which I might speak of many things; but I shall take notice only of two, because they manifest the particular concern and agency of the infinitely wise Creator. The

1. Is, That man's invention should reach to such a great variety of matters; that it should hit upon every thing that may be of any use, either to himself,

*Sed varias jubet ire vias, variosque labores
Suscipere, ut vario cultu sit pulchrior orbis.*

Paling in Scorp.

*Οὕτως ἔ πάντοτε θεὸς χαρίεντά διδωσι
Ἀνθρώποις, etc.*

* Ita non omnibus hominibus sua dona dat Deus, neque bonam indolem, neque prudentiam, nec eloquentiam: alius namque vultum habet deformem; sed Deus formam eloquentia ornatus, etc. Hom. Odyf. 8. The like also in Iliad. l. 13.

(*f*) Although Solomon declares, Eccl. xii. 12. 'That much study is a weariness to the flesh;' yet we see with what pleasure and assiduity many apply themselves to it. Thus Cicero tells of Cato, whom he casually found in Lucullus's library; 'M. Catonem vidi in bibliotheca sedentem, multis circumfusus Stoicorum libris. Erat enim, ut scis, in eo inexhausta aviditas legendi, nec satiari poterat: quippe ne reprehensionem quidem vulgi inanem reformidans, in ipsa curia soleret legere sæpe dum senatus cogeretur——ut Heluo librorum——videbatur.' Cic. de Finibus l. 3. c. 2.

(*g*) 'Mentem hominis, quamvis eam non videas, ut Deum non vides, tamen ut Deum agnosceis ex operibus ejus, sic ex memoria rerum, et inventione, et celeritate motus, omnique pulchritudine virtutis vim divinam mentis agnosceito.' Cic. Tusc. Quæst. l. 1. c. 29.

or to human society, or that may any ways promote, what in him lies, the benefit of this lower part of the creation.

For the illustration of this, I might take a view of all the arts and sciences, the trades, yea, the very tools they perform their labours, and contrivances with, as numerous as their occasions and contrivances are various. Indeed, what is there that falleth under the reach of man's senses, that he doth not employ to some use and purpose, for the world's good? The celestial bodies, the sun, the moon, with the other planets, and the fixed stars, he employs to the noble uses of astronomy, navigation, and geography. And, what a noble acumen, what a vast reach must the soul be endowed with, to invent those curious sciences of geometry and arithmetic, both specious, and in numbers; and those nice and various instruments, made use of by the geometrician, astronomer, geographer, and sailor! And lastly, what a wonderful sagacity is shewn in the business of optics, and particularly in the late invention of the telescope; wherewith new wonders are discovered among God's works, in the heavens, as there are here on earth, with the microscope, and other glasses!

And as for this lower world, what material is there to be found; what kind of earth, or stone, or metal; what animal, tree, or plant, yea, even the very shrubs of the field; in a word, what of all the excellent variety, the Creator has furnished the world with, for all its uses and occasions, in all ages; what, I say, that man's contrivance doth not extend unto, and make some way or other advantageous to himself, and useful for building, clothing, food, physic, or for tools or utensils, or for even only pleasure and diversion!

But now considering the great power and extent of human invention,

2. There is another thing, that doth farther demonstrate the super-intendence of the great Creator

and Conservator of the world ; and that is, that things of great, and absolutely necessary use, have soon, and easily occurred to the invention of man ; but things of little use, or very dangerous use, are rarely and slowly discovered, or still utterly undiscovered. We have as early as the Mosaic history, an account of the inventions of the more useful crafts and occupations : thus, Gen. iii. 23. ‘ Adam was sent forth ‘ from the garden of Eden, by God himself, to till ‘ the ground.’ And in the next chapter, his two sons Cain and Abel ; the one was of the same occupation, a tiller of the ground, the other a keeper of sheep (*h*). And the posterity of these are in the latter end of Gen. iv. recorded, ‘ Jabel, to have been ‘ the father of such as dwell in tents (*i*) ;’ i. e. he was the inventor of tents, and pitching those moveable houses in the fields, for looking after, and depasturing their cattle in the deserts, and uncultivated world. ‘ Tubal-Cain was an instructor of every artificer in brass and iron (*k*),’ or the first that found out the art of ‘ melting, and malleating metals (*l*),’ and making them useful for tools, and other necessary implements. And his sister Naamah, whose name is only mentioned, is by some thought to have been the inventor of spinning and clothing. Yea, the very art of music is thus early ascribed to Jubal (*m*) ; so indulgent was the Creator to find a means to divert melancholy, to cheer the spirits, and to entertain and please mankind. But for things of no use, or but little use, or of pernicious consequence, either they have been much later thought of, and with great difficulty, and perhaps danger too, brought to pass ; or else they still are, and perhaps will always remain, exercises of the wit and invention of men.

(*h*) Gen. iv. 2.(*i*) Ver. 20.(*k*) Gen. iv. 22.(*l*) *Σπουδόνος*, the LXX call him, i. e. a worker with an hammer.(*m*) Gen. iv. 21.

Of this we might give divers instances: in mathematics, about squaring the circle (*n*); in mechanics (*o*), about the art of flying; and in navigation, about finding the longitude. These things, although some of them in appearance innocent, yea, perhaps very useful, yet remain for the most part secret; not because the discovery of most of them is more impossible, or difficult than of many other things, which

(*n*) Although the quadrature of the circle hath in former ages exercised some of the greatest mathematical wits; yet nothing has been done in that way so considerable, as in and since the middle of the last century; when in the year 1657, those very ingenious and great men, Mr William Neil, and my lord Brouncker, and Sir Christopher Wren afterwards, in the same year, geometrically demonstrated the equality of some curves to a strait line. Soon after which, others at home, and abroad, did the like in other curves. And not long afterwards, this was brought under an analytical calculus: the first specimen whereof, that was ever published, Mr Mercator gave in 1688, in a demonstration of my lord Brouncker's quadrature of the hyperbola, by Dr Wallis's reduction of a fraction, into an infinite series by division. But the penetrating genius of Sir Isaac Newton had discovered a way of attaining the quantity of all quadrable curves analytically, by his method of fluxions, some time before the year 1688, as I find very probable from an historical account, in a long letter of Mr Collins, written in his own hand, and sent to Richard Townley, Esq; of Lancashire, whose papers are in my hands. In that letter Mr Collins saith, that 'in September 1668, Mr Mercator published his *Logarithmotechnica*, one of which he soon sent to Dr Barrow, who thereupon sent him up some papers of Mr Newton's [now Sir Isaac]; by which, and former communications made thereof by the author, to the doctor, it appears, that the said method was invented some years before by the said Mr Newton, and generally applied.' And then he goes on to give some account of the method; what it performs in the circle, etc. what Mr Gregory had done in that kind, 'who intended to publish somewhat in Latin about it, but would not anticipate Mr Newton, the first inventor thereof;' with much more of this nature. The design, I find, of that indefatigable promoter of mathematics, Mr Collins, was to acquaint Mr Townley, in his letter, with what had been done; and to get the assistance of that ingenious gentleman, towards the completing a body of algebra.

(*o*) I do not mention here the perpetual motion, which hath exercised the mechanical wits for many ages, because it is a thing impossible, if not a contradiction: as the before-commended Dr Clarke asserts in *Rohaul. Phys.* p. 133.

have met with a discovery; nor is it for want of man's diligence therein, or his careful pursuit and inquiry after them, (for perhaps, nothing already discovered hath been more eagerly sought after); but with much better reason (I am sure with greater humility and modesty) we may conclude it is, because the infinitely wise Creator, and Ruler of the world, hath been pleased to lock up these things from man's understanding and invention, for some reasons best known to himself, or because they might be of ill consequence, and dangerous amongst men.

As in all probability the art of flying would particularly be: an art which in some cases might be of good use, as to the geographer and philosopher; but in other respects, might prove of dangerous and fatal consequence: as for instance, by putting it in man's power to discover the secrets of nations and families more than is consistent with the peace of the world for men to know; by giving ill men greater opportunities to do mischief, which it would not lie in the power of others to prevent; and, as one observes (*p*), by making men less sociable: 'For upon every true or false ground of fear, or discontent, and other occasions, he would have been fluttering away to some other place; and mankind, instead of cohabiting in cities, would, like the eagle, have built their nests upon rocks.'

That this is the true reason of these matters, is manifest enough from holy scripture; and reason (*q*) also gives its suffrage thereto. The scripture expressly tells us, that 'every good gift, and every perfect gift, is from above, and cometh down from the Father of lights,' St James i. 17. Solomon, Prov. ii. 6. saith, 'The Lord giveth wisdom; out of his mouth cometh knowledge and understanding.' And Elihu is very express, Job xxxii. 8. 'But there is a

(*p*) Grew's Cosmol. Sacr. l. 1. c. 5. sect. 25.

(*q*) 'Nemo igitur vir magnus sine aliquo afflatu divine unquam fuit.' Cic. de Nat. Deor. l. 2. c. 65.

‘ spirit in man, and the inspiration of the Almighty
 ‘ giveth them understanding; Προὴ παντοκράτορος ἐστὶν ἡ
 διδασκνσα, as the LXX render it, ‘ The inspiration,
 ‘ the afflatus of the Almighty, is their instructor,
 ‘ mistress, or teacher.’ And in scripture, not only
 the more noble, superior acts of wisdom or science,
 but much inferior also, bear the name of wisdom,
 knowledge, and understanding, and are ascribed unto
 God. It is well known that Solomon’s wisdom is
 wholly ascribed unto God; and the wisdom and un-
 derstanding which God is said to have given him,
 1 Kings iv. 29. is particularly set forth in the following
 verses, by his great skill in moral and natural philoso-
 phy, in poetry, and probably in astronomy, geome-
 try, and such other of the politer sciences, for which
 Egypt, and the Eastern nations were celebrated of
 old (r); ‘ And Solomon’s wisdom excelled the wis-
 ‘ dom of all the children of the east country, and all
 ‘ the wisdom of Egypt. For he was wiser than all
 ‘ men, than Ethan, etc. And he spake 3000 pro-
 ‘ verbs; and his songs were 1005. And he spake of
 ‘ trees, from the cedar to the hyssop of the wall,
 ‘ (i. e. of all sorts of plants); also of beasts, fowl,
 ‘ creeping things, and fishes.’ So likewise the wis-
 dom of Daniel and his three companions, is ascribed
 unto God, Dan. i. 17. ‘ As for these four children,
 ‘ God gave them knowledge, and skill in all learning
 ‘ and wisdom; and Daniel had understanding in all
 ‘ visions and dreams.’ And accordingly in the next
 chapter, Daniel acknowledgeth and praiseth God, ver.
 20, 21. ‘ Daniel answered and said, Blessed be the
 ‘ name of God for ever and ever, for wisdom and
 ‘ might are his.--He giveth wisdom unto the wise, and

(r) Egypt, and some of the Eastern nations, are celebrated for
 their skill in polite literature; both in scripture and profane
 story: Job was of those parts; so were the Σοφοὶ and Μαγῶι,
 the Brachmans and Gymnosophists. Moses and Daniel had their
 education in these parts: and Pythagoras, Democritus, and o-
 thers, travelled into these parts for the sake of learning.

‘knowledge to them that know understanding.’ But not only skill in the superior arts and sciences, but even in the more inferior mechanic arts, is called by the same names, and ascribed unto God: thus for the workmanship of the tabernacle, *Exod. xxxi. 2. to ver. 6.* ‘See, I have called Bezaleel; and I have filled him with the Spirit of God, in wisdom, and in understanding, and in all manner of workmanship: to devise cunning works, to work in gold, silver, and brass; and in cutting of stones, to set them; and in carving of timber, to work in all manner of workmanship.’ So the spinsters, weavers, and other crafts-people, are called wise-hearted, *Exod. xxxiv. 10. 25.* and other places. And in *Exod. xxxvi. 1,* etc. the Lord is said to have put this wisdom in them, and understanding to know how to work all these manner of works, for the service of the sanctuary. And lastly, to name no more instances, Hiram the chief architect of Solomon’s temple, is in *1 Kings vii. 14.* and *2 Chron. ii. 14.* called ‘a cunning man, filled with wisdom and understanding, to work in gold, silver, brass, iron, stone, timber, purple, blue, fine linen, and crimson; also to grave, and find out every device which should be put to him.’

Thus doth the word of God ascribe the contrivances and crafts of men, to the agency, or influence of the Spirit of God, upon that of man. And there is the same reason for the variety of genii, or inclinations of men also; which from the same scriptures may be concluded to be a designation, and transaction of the same almighty Governor of the world’s affairs. And who indeed, but HE, could make such a divine substance, endowed with those admirable faculties and powers, as the rational soul hath; a being to bear the great Creator’s vicegerency in this lower world; to employ the several creatures; to make use of the various materials; to manage the grand business; and to survey the glories of all the

visible works of God! a creature, without which this lower world would have been a dull, uncouth and desolate kind of globe! who, I say, or what less than the infinite God, could make such a rational creature, such a divine substance as the soul! For if we should allow the Atheist any of his nonsensical schemes, the Epicurean his fortuitous concurrence of atoms, or the Cartesian (*s*) his created matter put in motion; yet with what tolerable sense could he, in his way, produce such a divine, thinking, speaking, contriving substance as the soul is; endowed exactly with such faculties, powers, and dispositions as the various necessities and occasions of the world require from such a creature! Why should not rather all the acts, the dispositions and contrivances of such a creature as man, if made in a mechanical way, and not contrived by God, have been the same? Particularly, why should he not have hit upon all contrivances of equal use, early, as well as many ages since? Why not that man have effected, as well as this, some thousands of years after? Why also should not all nations, and all ages (*s*), improve in every thing,

(*s*) As we are not to accuse any falsely, so far be it from me to detract from so great a man as Monsieur Cartes was; whose principles, although many have perverted to atheistical purposes, and whose notions have, some of them, but an ill aspect, yet I am unwilling to believe he was an Atheist; since in his *Principia Philosophiae*, and other of his works, he vindicates himself from this charge; and frequently shews seemingly a great respect for religion: besides that, many of his suspicious opinions are capable of a favourable interpretation, which will make them appear in a better form: thus when he discardeth final causes from his philosophy, it is not a denial of them; but only excluding the consideration of them, for the sake of free philosophising; it being the business of a divine, rather than a philosopher, to treat of them.

(*s*) For ages of learning and ignorance, we may compare the present, and some of the ages before the reformation. The last century, and the few years of this, have had the happiness to be able to vie with any age for the number of learned men of all professions, and the improvement made in all arts and sciences; too many, and too well known to need a specification.

as well as this, or that age, or nation only (t)? Why should the Greeks, the Arabians, the Persians, or

But for ignorance, we may take the ninth age, and so down to the reformation; even as low as queen Elizabeth, although learning began to flourish; yet we may guess how matters stood, even among the clergy, by her 53 Injunct. An. 1559. 'Such as are but mean readers should peruse over before, once or twice, the chapters and homilies, to the intent they may read to the better understanding of the people, the more encouragement of godliness.' Spar. Collect. p. 82. But this is nothing, in comparison to the ages before, when a monk said, 'Graecum non est legi;' or as Espencaeus more elegantly hath it, 'Graece nosse suspectum, Hebraice prope haereticum.' Which suspicion, said the learned Hakewill, Rhomigius surely was not guilty of, in commenting upon *diffamatus*, 1 Thess. i. 8. who saith, that St Paul somewhat improperly put that for *divulgatus*, not being aware that St Paul wrote in Greek, and not in Latin. Nay, so great was their ignorance, not only of Greek, but of Latin too, that a priest baptized 'in nomine Patria, et Filia, Spiritua sancta.' Another suing his parishioners for not paving his church, proved it from Jer. xvii. 18. 'Paveant illi, non paveam ego.' Some divines in Erasmus's time undertook to prove heretics ought to be burnt, because the apostle said, 'Haereticum devita.' Two friars disputing about a plurality of worlds, one proved it from 'Annon decem sunt facti mundi?' The other replied, 'Sed ubi sunt novem?' And notwithstanding their service was read in Latin, yet so little was that understood, that an old priest in Henry VIII read *mumpsimus Domine* for *sumpsimus*: and being admonished of it, he said, he had done so for thirty years, and would not leave his old *mumpsimus* for their new *sumpsimus*. Vide Hakewill, Apol. l. 3. c. 7. sect. 2.

(t) 'There is, it seems, in wits and arts, as in all things beside, a kind of circular progress: they have their birth, their growth, their flourishing, their falling, their fading; and within a while after, their resurrection, and flourishing again. The arts flourished for a long time among the Persians, the Chaldaeans, the Egyptians—But afterwards the Graecians got the start of them, and are now become as barbarous themselves, 'as formerly they esteemed all besides themselves to be.' About the birth of Christ, learning began to flourish in Italy, and spread all over Christendom, till the Goths, Huns, and Vandals, ransacked the libraries, and defaced almost all the monuments of antiquity: so that the lamp of learning seemed to be put out, for near the space of 1000 years, till the first Mansor, king of Africa and Spain, raised up, and spurred forward the Arabian wits, by great rewards and encouragements. Afterwards Petrarch opened such libraries as were undemolished. He was seconded by Boccace, and John of Ravenna, and soon after by Aretine, Philolphus, Valla, &c. And those were followed by Aeneas Sylvius, Ange-

the Egyptians of old, so far exceed those of the same nations now? Why the Africans and Americans, so generally ignorant and barbarous, and the Europeans, for the most part, polite and cultivated, addicted to arts and learning? How could it come to pass, that the use of the magnet (*u*), print-

lus Politianus, Hermolaus Barbarus, Marfilius Ficinus, and Joh. Picus of Mirandula. These were backed by Rud. Agricola, Rencline, Melancthon, Joach. Camerarius, Wolph. Lazius, Beat. Rhenanus, Almains: by Erasmus of Rotterdam; Vives, a Spaniard; Bembus, Sadoletus, Eugubinus, Italians: Turnebus, Muretus, Ramus, Pithaeus, Budaeus, Amiot, Scaliger, Frenchmen: Sir Tho. More, and Linaker, Englishmen. And about this time, even those northern nations yielded their great men; Denmark yielded Olaus Magnus, Holser, Tycho Brahe, and Hemingius; and Poland, Hostus, Frixius, and Crumerus. But to name the worthies that followed these, down to the present time, would be endless and next to impossible. See therefore Hakewill's *Apol.* l. 3. c. 6. sect. 2.

(*u*) Dr Gilbert, the most learned and accurate writer on the magnet, shews, that its attractive virtue was known as early as Plato and Aristotle; but its direction was a discovery of later ages. He saith, 'Superiori aevo 300 aut 400 labentibus annis, motus magneticus in Boream et Austrum repertus, aut ab hominibus rursus recognitus fuit.' *De Mag.* l. 1. c. 1. But who the happy inventor of this lucky discovery was, is not known. There is some, not inconsiderable, reason to think our famous countryman, Rog. Bacon, either discovered, or at least knew of it. But for its use in navigation, Dr Gilbert saith, 'in regno Neapolitano Melphitani omnium primi, uti ferunt, pyxidem instruebant nauticam.' edocti a cive quodam Jol. Goia, A. D. 1300. *ibid.* If the reader hath a mind to see the arguments for the invention being as old as Solomon's or Plautus's time, or of much younger date, he may consult Hakewill, *ib.* c. 10. sect. 4. or Purchas Pilgr. l. 1. c. 1. sect. 1.

As to the magnetic variation, Dr Gilbert attributes the discovery of it to Sebastian Cabott. And the inclination, or dipping of the needle, was the discovery of our ingenious Rob. Norman. And lastly, the variation of the variation was first found out by the ingenious Mr H. Gellibrand, Astr. Prof. of Gresh. Coll. about 1634. Vide Gellibr. *Disc. Math.* on the Variation of the Magnetic Needle, and its Variat. anno 1635.

But since that, the before-commended Dr Hally, having formerly, in *Phil. Trans.* No 148, and 195, given a probable hypothesis of the variation of the compass, did, in the year 1700, undertake a long and hazardous voyage, as far as the ice near the south pole, in order to examine his said hypothesis, and to make system of the magnetical variations: which being soon after published, has been since abundantly confirmed by the French, and

ing (*v*), clocks (*w*), telescopes (*x*), and an hundred things besides, should escape the discovery of Archi-

may be seen in several of the late *Memoires de Physique et de Mathematique*, published by the French Academie des Sciences.

To these discoveries, I hope the reader will excuse me, if I add one of my own, which I deduced some years ago, from some magnetical experiments and observations I made; which discovery I also acquainted our Royal Society with, some time since, viz. that as the common, horizontal needle is continually varying up and down, towards the E. and W. so is the dipping needle varying up and down, towards or fromwards the zenith, with its magnetic tendency, describing a circle round the pole of the world, as I conceive, or some other point. So that if we could procure a needle so nicely made, as to point exactly according to its magnetic direction, it would, in some certain number of years, describe a circle of about 13 gr. radius round the magnetic poles northerly and southerly. This I have for several years suspected, and have had some reason for it too, which I mentioned three or four years ago, at a meeting of our Royal Society; but I have not yet been so happy to procure a tolerable good dipping-needle, or other proper one to my mind, to bring the thing to sufficient test of experience, as in a short time I hope to do, having lately hit upon a contrivance that may do the thing.

(*v*) It is uncertain who was the inventor of the art of printing, every historian ascribing the honour thereof to his own city or country. Accordingly some ascribe the invention of it to John Gутtenburg, a knight of Argentine, about 1440, and say that Faustus was only his assistant. Bertius ascribes it to Laurence John, of Haerlem, and saith, Fust, or Faust, stole from him both his art and tools. And, to name no more, some attribute it to John Fust or Faust, and Peter Schoeffer (called by Fust, in some of his imprimaturs, Pet. de Gernesheim puer meus). But there is now to be seen at Haerlem, a book or two printed by Lau. Coster, before any of these, viz. in 1430, and in 1432. (See Mr Ellis's Letter to Dr Tyson, in *Phil. Transf.* No. 286). But be the first inventor who it will, there is however great reason to believe the art received great improvements from Faust, and his son-in-law Schoeffer, the latter being the inventor of metal-line types, which were cut in wood before, first in whole blocks, and afterwards in single types or letters. See my learned friend Mr Wanley's observations, in *Phil. Transf.* No. 288, and 310.

(*w*) Concerning the antiquity and invention of clocks and clock-work, I refer the reader to a little book, called, *The Artificial Clock-maker*, chap. 6. where there is some account of the ancients inventions in clock-work, as Archimedes's sphere, Ctesibius's clock, etc.

(*x*) The invention of telescopes, Hieron. Syrturus gives this account of. 'Prodiit Anno 1609, seu genius, seu alter vir adhuc incognitus, Hollandi specie, qui Middleburgi in Zelandia con-

medes, Anaximander, Anaximenes, Possidonius, or other great virtuosos of the early ages, whose contrivances of various engines, spheres, clepsydrae, and other curious instruments, are recorded (y)? And

‘ venit Joh. Lippersein—Jussit perspicilla plura tam cava quam convexa, confici. Condicto die rediit, absolutum opus capiens, atque ut statim habuit prae manibus, bina suscipiens, cavum scil. et convexum, unum et alterum oculo admovebat, et sensim dimovebat, sive ut punctum concursus, sive ut artificis opus probaret, postea abiit. Artifex, ingenii minime expertus, et novitatis curiosus coepit idem facere et imitari,’ etc. V. Mus. Wor. l. 4. c. 7.

(y) Among the curious inventions of the ancients, Archytas's dove was much famed; of which Aul. Gellius gives this account: ‘ Scripserunt simulachrum columbae e ligno ab Archyta ratione quadam disciplinaque mechanica factum, volasse: ita erat scilicet libramentis suspensum, et aura spiritus inclusa atque occulta concitum.’ Noct. Attic. l. 10. c. 12. The same eminent Pythagorean philosopher, as Favorinus in Gellius calls him, is by Horace accounted a noble geometrician too, ‘ Te maris et terrae, numeroque carentis arenae Mensorem, Archyta.’ Among the rest of his inventions, childrens rattles are ascribed to him. Aristotle calls them, ‘ Ἀρχύτου πλαταγή,’ Polit. 8. i. e. Archytas's rattle. And Diogenianus, the grammarian, gives the reason of his invention, ‘ Ἀρχύτου πλαταγή πρὸ τῶν, etc.’ ‘ That Archytas's rattle was to quiet children; for he having children, contrived the rattle, which he gave them to prevent their tumbling’ [διασκελεῖν,] other things about the house.’

To these contrivances of Archytas, we may add Regiomontanus's wooden eagle, ‘ which flew forth of the city, aloft in the air, met the emperor a good way off, coming towards it, and having saluted him, returned again, waiting on him to the city gates.’ Also his iron fly, which at a feast ‘ flew forth of his hands, and taking a round returned thither again.’ Vide Hakewill, ubi supra, c. 10. sect. 1.

As to other inventions of the ancients, such as of letters, bricks, and tiles, and building houses, with the saw, rule, and plumber, the lath, augre, glue, etc. also the making brass, gold, and other metals; the use of shields, swords, bows, and arrows, boots, and other instruments of war; the pipe, harp, and other musical instruments; the building of ships, and navigation, and many other things besides; the inventors of these, as reported by ancient heathen authors, may be plentifully met with in Pliny Nat. Hist. l. 7. c. 36.

But in this account of Pliny, we may observe whence the ancients, even the Romans themselves in some measure, had their accounts of these matters, viz. from the fabulous Greeks, who were fond of ascribing every thing to themselves. ‘ The truth is, (saith the most learned bishop Stillingfleet), there is nothing in the world useful or beneficial to mankind, but they have

why cannot the present or past age, so eminent for polite literature, for discoveries and improvements in all curious arts and businesses (perhaps beyond any known age of the world; why cannot it, I say) discover those hidden *Quæsitæ*, which may probably be reserved for the discovery of future and less learned generations?

Of these matters, no satisfactory account can be given by any mechanical hypothesis, or any other way, without taking in the superintendence of the great Creator and Ruler of the world; who oftentimes doth manifest himself in some of the most considerable of those works of men, by some remarkable transactions of his providence, or by some great revolution or other happening in the world thereupon. Of this I might instance in the invention of printing (z), succeeded first by a train of learned men, and the revival of learning, and soon after that by the reformation, and the much greater improvements of learning at this day. But the most considerable in-

made a shift to find the author of it among themselves. If we inquire after the original of agriculture, we are told of Ceres and Triptolemus; if of pasturage, we are told of an Arcadian pan; if of wine, we presently hear of a Liber Pater; if of iron instruments, then who but Vulcan! if of music, none like to Apollo. If we press them then with the history of other nations, they are as well provided here; if we inquire an account of Europe, Asia, or Libya; for the first, we are told a fine story of Cadmus's sister; for the second, of Prometheus's mother of that name; for the third, of a daughter of Eraphus. And so the learned author goes on with other particular nations, which they boasted themselves to be the founders of. "Only the grave Athenians thought scorn to have any father assigned them, their only ambition was to be accounted 'aborigines et genuini terræ.'" But the ignorance and vanity of the Greek history, that learned author hath sufficiently refuted. Vide Stil-fleet's *Orig. Sacr.* part 1. book 1. chap. 4.

(2) Whether printing was invented in 1440, as many imagine, or was sooner practised, in 1430, or 1432, as Mr Ellis's account of the Dutch inscription, in *Phil. Transf.* No. 286. doth import; is however manifest, how great an influence, as it was natural, this invention had in the promoting of learning soon afterwards, mentioned before in note (v), p. 273. After which followed the reformation, about the year 1517.

stance I can give is, the progress of Christianity, by means of the civilized disposition, and large extent of the Roman empire. The latter of which, as it made way for human power, so the former made way for our most excellent religion into the minds of men. And so I hope, and earnestly pray, that the omnipotent and all-wise Ruler of the world will transact the affairs of our most holy religion, ere it be long, in the heathen world; that the great improvements made in the last, and present age, in arts and sciences, in navigation and commerce, may be a means to transport our religion, as well as name, through all the nations of the earth. For we find that our culture of the more polite and curious sciences, and our great improvements in even the mechanic arts, have already made a way for us into some of the largest and farthest distant nations of the earth; particularly into the great empire of China (*aa*).

And now, before I quit this subject, I cannot but make one remark, by way of practical inference, from what has been last said, and that is, since it appears, that the souls of men are ordered, disposed, and actuated by God, even in secular, as well as spiritual Christian acts, a duty ariseth thence on every

(*aa*) The Chinese being much addicted to judicial astrology, are great observers of the heavens, and the appearances in them. For which purpose they have an observatory at Pekin, and five mathematicians appointed to watch every night; four towards the four quarters of the world, and one towards the zenith, that nothing may escape their observation: which observations are the next morning brought to an office to be registered. But notwithstanding this their diligence for many ages, and that the emperor hath kept in his service above 100 persons, to regulate the kalendar, yet are they such mean astronomers, that they owe the regulation of their kalendar, the exactness in calculating eclipses, etc. to the Europeans; which renders the European mathematicians so acceptable to the emperor, that father Verbiest, and divers others, were not only made principals in the observatory, but put into places of great trust in the empire, and had the greatest honours paid them at their deaths. Vide La Comte Mem. of China, Letter 2, etc.

man, to pursue the ends, and answer all the designs of the divine providence, in bestowing his gifts and graces upon him. Men are ready to imagine their wit, learning, genius, riches, authority, and such like, to be works of nature, things of course, or owing to their own diligence, subtilty, or some secondary causes; that they are masters of them, and at liberty to use them as they please, to gratify their lust or humour, and satisfy their depraved appetites. But it is evident, that these things are the gifts of God, they are so many talents entrusted with us by the infinite Lord of the world, a stewardship, a trust reposed in us; for which we must give an account at the day when our Lord shall call; according to the parabolical representation of this matter by our blessed Saviour, Matth. xxv. 14.

Our duty then is not to abuse these gifts of God, not to neglect the gift that is in us, not to hide our talent in the earth; but, as St. Paul exhorteth Timothy, 2 Tim. i. 6. we must 'stir up the gift of God which is in us,' and not let it lie idle, concealed, or dead; but we must ἀναζωπυρεῖν τὸ χάρισμα, 'blow it up, and enkindle it,' as the original imports; we must improve and employ our gift to the glory of the giver; or, in that ministration, that use and service of the world, for which he gave it. Our stewardship, our craft, our calling, be it that of ambassadors of heaven, committed to us, as it was to Timothy (*bb*), by the laying on of hands; or be it the more secular business of the gentleman, tradesman, mechanic, or only servant; nay, our good genius, our propensity to any good, as suppose to history, mathematics, botany, natural philosophy, mechanics, etc.; I say, all these occupations, in which the providence of God hath engaged men, all the inclinations to which his Spirit hath disposed them, ought to be discharged with that diligence, that care

(*bb*) 1 Tim. iv. 14. 2 Tim. i. 6.

and fidelity, that our great Lord and Master may not say to us, as was said to the unfaithful steward, Luke xvi. 2. 'Give an account of thy stewardship, for thou mayst be no longer steward;' but that he may say, as it is in the parable before cited, Matth. xxv. 21. 'Well done, thou good and faithful servant, thou hast been faithful over a few things, I will make thee ruler over many things, enter thou in to the joy of thy Lord.' Since now the case is thus, let us be persuaded to follow Solomon's advice, Eccl. ix. 10. 'Whatsoever thy hand findeth to do, do it with thy might' (cc): 'Lay hold on every occasion that presents itself, and improve it with the utmost diligence; because now is the time of action, both in the employments of the body and of the mind; now is the season of studying either arts and sciences, or wisdom and virtue, for which thou wilt have no opportunities in the place whither thou art going in the other world.' "For there is no work, nor device, nor knowledge, nor wisdom in the grave whither thou goest."

CH A P. II.

Of Man's BODY, particularly its POSTURE.

HA VING thus, as briefly as I well could, surveyed the Soul, let us next take a view of Man's Body. Now, here we have such a multiplicity of the most exquisite workmanship, and of the best contrivance, that if we should strictly survey the body from head to foot, and search only into the known parts, and many more that lie undiscovered, we should find too large and tedious a task to be dispatched. I shall therefore have time only to take a transient and general kind of view of this admirable ma-

(cc) Bishop Patrick in loc.

chine, and that somewhat briefly too, being prevented by others, particularly two excellent authors of our own (*a*), who have done it on the same account as myself. And the

I. Thing that presents itself to our view, is the erect posture (*b*) of man's body; which is far the most, if not the only commodious posture for a rational creature, for him that hath dominion over the other creatures, for one that can invent useful things, and practise curious arts. For, without this erect posture, he could not have readily turned himself to every business, and on every occasion. His hand (*c*)

(*a*) Mr Ray, in his *Wisdom of God* manifested in the works of creation, part 2. And Dr Cockburn's *Essays on Faith*, part 1. essay 5.

(*b*) 'Ad hanc providentiam naturae tam diligentem' [of which he had been before speaking] 'tamque solertem adjungi multa possunt, e quibus intelligatur, quantae res hominibus a Deo, quamque eximiae tributae sunt: qui primum eos homo excitatos, celsos, et erectos constituit, ut deorum cognitionem, coelum intuentes, capere possent. Sunt enim e terra homines non ut incolae, atque habitatores, sed quasi spectatores superarum rerum, atque coelestium, quarum spectaculum ad nullum aliud genus animantium pertinet.' Cic. de Nat. Deor. l. 2. c. 56.

(*c*) 'Ut autem sapientissimum animalium est homo, sic et manus sunt organa sapienti animali convenientia. Non enim quia manus habuit, propterea est sapientissimum, ut Anaxagoras dicebat; sed quia sapientissimum erat, propter hoc manus habuit, ut rectissime censuit Aristoteles. Non enim manus ipsae hominem artes docuerunt, sed ratio. Manus autem ipsae sunt artificum organum,' etc. Galen. de usu part. l. 1. c. 3. After which, in the rest of his first book, and part of the second, he considers the particulars of the hand, in order to inquire, as he saith, ch. 5. 'Num eam omnino constitutionem habeat [manus] qua meliorem aliam habere non potuit.'

Of this part, and indeed of the other parts of human bodies, he gives so good an account, that I confess I could not but admire the skill of that ingenious and famed Heathen. For an example, because it is a little out of the way, I shall pitch upon his account of the different length of the fingers, lib. 1. c. 24. The reason of this mechanism, he saith, is, that the tops of the fingers may come to an equality, 'Cum magnas aliquas moles in circuitu comprehendunt, et cum in seipsis humidum vel parvum corpus continere conantur.—Apparent vero in unam circuli circumferenceiam convenire digiti quinque in actionibus hujusmodi, maxime quando exquisitè sphaericum corpus comprehendunt.'

particularly could not have been in so great a readiness to execute the commands of the will, and dictates of the soul. His eyes would have been the most prone, and incommodiously situated of all animals; but, by this situation, he can cast his eyes upwards, downwards, and round about him; he hath a glorious hemisphere of the heavens (*d*), and an ample horizon on earth (*e*), to entertain his eye.

And this evenness of the fingers ends, in grasping spherical and other round bodies, he truly enough saith, makes the hold the firmer. And it seems a noble and pious design he had in so strictly surveying the parts of man's body, which take in his own translated words: 'Cum multa namque esset apud veteres, tam medicos, quam philosophos, de utilitate particularum dissensio (quidem enim corpora nostra nullius gratia esse facta existimant, nullaque omnino arte; alii autem et alicujus gratia, et artificiose,—) primum quidem tantae hujus dissensionis *κρίτηριον* invenire studui: deinde vero et unam aliquam universalem methodum constituere, qua singularem partium corporis, et eorum quae illis accidunt utilitatem invenire possemus.' Ibid. cap. 8.

(*d*) Pronaque cum spectant animalia caetera terram,
Os homini sublime dedit, coelumque tueri
Jussit, et erectos ad sidera tollere vultus.

Ovid. Metam. l. i. car. 84.

(*e*) If any should be so curious, to desire to know how far a man's prospect reacheth, by means of the height of his eye, supposing the earth was an uninterrupted globe; the method is a common case of right-angled plain triangles, where two sides, and an opposite angle are given: thus in Fig. 4. *A H B* is the surface, or a great circle of the terraqueous globe; *C* the centre, *H C* its semidiameter, *E* the height of the eye; and forasmuch as *H E* is a tangent, therefore the angle at *H* is a right angle: so that there are given *H C* 398,386 milès, or 21,034,781 English feet, according to book ii. chap. 2. note (*s*), p. 70. *C E* the same length with the height of the eye, on the mast of a ship, or at only a man's height, etc. added to it; and *E H C* the opposite right angle. By which three parts given, it is easy to find all the other parts of the triangle. And first, the angle at *C*, in order to find the side *H E*, the proportion is, as the side *C E*, to the angle at *H*; so the side *H C*, to the angle at *E*, which being subtracted out of 90 gr. the remainder is the angle at *C*. And then, as the angle at *E* is to its opposite side *H C*, or else as the angle at *H* is to its opposite side *C E*; so the angle at *C* to its opposite side *E H*, the visible horizon. Or the labour may be shortened, by adding together the logarithm of the sum of the two given sides, and the logarithm of their difference; the half of which two logarithms is the logarithm of the side requir'd.

And as this erection of man's body is the most complete posture for him; so if we survey the provision made for it, we find all done with manifest design, the utmost art and skill being employed therein. To pass by the particular conformation of many of the parts, the ligaments and fastenings to answer this posture; as the fastenings, for instance, of the pericardium to the diaphragm, (which is peculiar to man (*f*); I say, passing by a deal of this nature, manifesting this posture to be an act of design), let us stop a little at the curious fabric of the bones, those pillars of the body. And how artificially do we find them made, how curiously placed from the head to the foot! The vertebrae of the neck and back-

red, nearly. For an example, we will take the two sides in yards; by reason scarce any table of logarithms will serve us farther. The semidiameter of the earth is 7,011,594 yards; the height of the eye is two yards more, the sum of both sides is 14,023,190.

Logar. of which sum is,	- - - - -	7,1468468
Logar. of two yards (the difference) is,	- - - - -	0,3010300
Sum of both Logar.	- - - - -	7,4478768
The half-sum,	- - - - -	3,7239384

is the Logarithm of 5296 yards = three miles, which is the length of the line E H, or distance the eye can reach at six feet height.

This would be the distance on a perfect globe, did the visual rays come to the eye in a strait line; but by means of the refractions of the atmosphere, distant objects on the horizon appear higher than really they are, and may be seen at a greater distance, especially on the sea; which is a matter of great use, especially to discover at sea the land, rocks, etc. and it is a great act of the divine providence, in the contrivance and convenience of the atmosphere, which by this means enlargeth the visible horizon, and is all one, as if the terraqueous globe was much larger than really it is. As to the height of the apparent above the true level; or, how much distant objects are raised by the refractions, the ingenious and accurate gentlemen of the French Academy Royal have given us a table in their Measures of the Earth, Art. 12.

(*f*) See book vi. chap. 5. note (*g*).

bone (*g*), made short and complanated, and firmly braced with muscles and tendons, for easy incurvations of the body; but withal for greater strength, to support the body's own weight, together with other additional weights it may have occasion to bear. The thigh-bones and legs long, and strong, and every way well fitted for the motion of the body. The feet accommodated with a great number of bones, curiously and firmly tacked together; to which must be added the ministry of the muscles (*h*), to answer all the motions of the legs and thighs, and at the same time to keep the body upright, and prevent its falling, by readily assisting against every vacillation thereof, and with easy and ready touches keeping the line of innexion and centre of gravity, in due place and posture (*i*).

And as the bones are admirably adapted to prop,

(*g*) See book iv. chap. 8. note (*c*), p. 173.

(*h*) The mechanism of the foot would appear to be wonderful, if I should descend to a description of all its parts; but that would be too long for these notes; therefore a brief account, (most of which I owe to the before-commended Mr Cheselden), may serve for a sample. In the first place, it is necessary the foot should be concave, to enable us to stand firm, and that the nerves and blood-vessels may be free from compression, when we stand or walk. In order thereunto, the long flexors of the toes cross one another at the bottom of the foot, in the form of a St Andrew's cross, to incline the lesser toes towards the great one, and the great one towards the lesser. The short flexors are chiefly concerned in drawing the toes towards the heel. The transversalis pedis draws the outsidess of the foot towards each other; and by being inserted into one of the sesamoid bones of the great toe, diverts the power of the abductor muscle, falsely so called, and makes it become a flexor. And lastly, the peroneus longus runs round the outer ankle, and obliquely forwards cross the bottom of the foot, and at once helps to extend the tarsus, to contract the foot, and to direct the power of the other extensors towards the hall of the great toe: hence the loss of the great toe is more than of all the other toes. See also Mr Cowper's Anat. tab. 28. etc.

(*i*) It is very well worth while to compare here what Borelli saith, de motu Animal. part. 1. cap. 18. De statione Animal. prop. 132. etc. To which I refer the reader, it being too long to recite here.

so all the parts of the body are as incomparably placed to poise it. Not one side too heavy for the other; but all in nice aequipoise: the shoulders, arms, and side, aequilibrated on one part; on the other, part of the viscera of the belly counterpoised with the weight of the scapular part, and that useful cushion of flesh behind.

And lastly, to all this we may add the wonderful concurrence, and ministry, of the prodigious number and variety of muscles, placed throughout the body for this service; that they should so readily answer to every posture, and comply with every motion thereof, without any previous thought or reflex act, so that, as the excellent Borelli saith (*k*), 'It is worthy of admiration, that in so great a variety of motions, as running, leaping, and dancing, nature's laws of aequilibration should always be observed; and when neglected, or wilfully transgressed, that the body must necessarily and immediately tumble down.'

C H A P. III.

Of the FIGURE and SHAPE of Man's BODY.

THE figure and shape of man's body, is the most commodious that could possibly be invented for such an animal; the most agreeable to his motion, to his labours, and all his occasions. For had he been a rational reptile, he could not have moved from place to place fast enough for his business, nor indeed have done any almost. Had he been a rational quadrupede, among other things, he had lost the benefit of his hands, those noble instruments of the most useful performances of the body. Had he been made a bird, besides many other great inconveniencies,

(*k*) Borel. *ibid.* prop. 142.

those before mentioned of his flying would have been some. In a word, any other shape of body, but that which the all-wise Creator hath given man, would have been as incommodious, as any posture but that of erect; it would have rendered him more helpless, or have put it in his power to have been more pernicious, or deprived him of ten thousand benefits, or pleasures, or conveniencies, which his present figure capacitates him for.

CHAP. IV.

Of the STATURE and SIZE of Man's BODY.

AS in the figure, so in the stature and size of man's body, we have another manifest indication of excellent design. Not too pygmean (*a*), nor too gigantic (*b*), either of which sizes would, in some particular or other, have been incommodious to himself, or to his business, or to the rest of his fellow-creatures. Too pygmean would have rendered him too puny a lord of the creation; too impotent, and unfit to manage the inferior creatures; would have exposed him to the assaults of the weakest animals, to the ravening appetite of voracious birds, and have put him in the way, and endangered his being trodden in the dirt by the larger animals. He would have been also too weak for his business, unable to carry burdens; and, in a word, to transact the greater part of his labours and concerns.

(*a*) What is here urged about the size of man's body, may answer one of Lucretius's reasons, why 'nil ex nihilo gignitur.' His argument is,

Denique cur homines tantos natura parare
Non potuit, pedibus qui pontum per vada possent
Transire, et magnos manibus divellere montes?

Lucret. l. 1. carm. 200.

(*b*) 'Haud facile fit ut quisquam et ingentes corporis vires, et ingenium subtile habeat.' Diodor. Sic. l. 17.

And on the other hand, had man's body been made too monstrously strong, too enormously gigantic (c), it would have rendered him a dangerous ty-

(c) Although we read of giants before Noah's flood, Gen. vi. 4. and more plainly afterwards in Numb. xiii. 33. yet there is great reason to think the size of man was always the same from the creation. For as to the Nephilim, or giants, in Gen. vi. the ancients vary about them; some taking them for great atheists, and monsters of impiety, rapine, tyranny, and all wickedness, as well as of monstrous stature, according as indeed the Hebrew signification allows.

And as for the Nephilim, in Num. xiii. which were evidently men of a gigantic size, it must be considered, that it is very probable, the fears and discontentments of the spies might add somewhat thereunto.

But be the matter as it will, it is very manifest, that in both these places, giants are spoken of as rarities and wonders of the age, not of the common stature. And such instances we have had in all ages; excepting some fabulous relations; such as I take to be that of Theutobochus, who is said to have been dug up, anno 1613, and to have been higher than the trophies, and 26 feet long; and no better I suppose the giants to have been that Ol. Magnus gives an account of, in his 5th book, such as Harthen and Starchater, among the men; and among the women, 'Reperta est (saith he) puella—in capite vulnerata, ac mortua, induta chlamyde purpurea, longitudinis cubitorum 50, latitudinis inter humeros quatuor.' Ol. Mag. Hist. l. 5. c. 2.

But as for the more credible relations of Goliath, ('whose height was six cubits and a span,' 1 Sam. xvii. 4. which, according to the late curious and learned Lord Bp. of Peterborough, is somewhat above 11 feet English; vid. Bp. Cumberland of Jewish weights and measures); of Maximinus the emperor, who was 9 feet high, and others in Augustus and other reigns, of about the same height: to which we may add, the dimensions of a skeleton, dug up lately in the place of a Roman camp near St Albans, by an urn, inscribed, Marcus Antoninus; of which an account is given by Mr. Cheselden, who judgeth by the dimensions of the bones, that the person was 8 feet high. Vide Phil. Trans. No. 333. These antique examples and relations, I say, we can match, yea, outdo, with modern examples; of which we have divers in J. Ludolph. Comment. in Hist. Æthiop. l. 1. c. 2. sect. 22. Magnus, Conringius, Dr Hakewill, and others. Which latter relates from Nannez, of porters and archers belonging to the emperor of China, of 15 feet high; and others from Purchas, of 10 and 12 feet high, and more. See the learned author's Apolog. p. 208.

These indeed exceed what I have seen in England: but in 1684, I myself measured an Irish youth, said to be not 19 years old, who was 7 feet and near 8 inches; and in 1697, a woman who was 7 feet 3 inches in height.

rant in the world, too strong (*d*) in some respects, even for his own kind, as well as the other creatures.

But for the ordinary size of mankind, in all probability, it was always, as I said, the same, as may appear from the monuments, mummies, and other ancient evidences to be seen at this day. The most ancient monument at this day, I presume, is that of the Cheops, in the first and fairest pyramid of Egypt; which was, no doubt, made of capacity every way sufficient to hold the body of so great a person as was intended to be laid up in it: but this we find, by the nice measures of our curious Mr Greaves, hardly to exceed our common coffins. 'The hollow part within,' saith he, 'is in length only 6,488 feet, and in breadth but 2,218 feet: the depth 2,860 feet. A narrow space, yet large enough to contain a most potent and dreadful monarch, being dead; to whom living all Egypt was too strait and narrow a circuit. By these dimensions, and by such other observations, as have been taken by me from several embalmed bodies in Egypt, we may conclude there is no decay in nature, (though the question is as old as Homer); but that the men of this age are of the same stature they were near 3000 years ago.' Vide Greaves of the Pyramid in 1638, in Ray's Collect. of Trav. tom. 1. p. 218.

To this more ancient, we may add others of a later date. Of which take these, among others, from the curious and learned Hakewill. The tombs at Pifa, that are some thousand years old, are not longer than ours; so is Athelstane's in Malmesbury church; so Sebba's in St Paul's of the year 693; so Etheldred's, etc. Apol. 216. etc.

The same evidence we have also from the armour, shields, vessels, and other utensils dug up at this day. The brass helmet dug up at Metaurum, which was not doubted to have been left there at the overthrow of Asdrubal, will fit one of our men at this day.

Nay, besides all this, probably we have some more certain evidence. Augustus was 5 feet 9 inches high, which was the just measure of our famous queen Elizabeth, who exceeded his height 2 inches, if proper allowance be made for the difference between the Roman and our foot. Vide Hakew. ib. p. 215.

(*d*) To the stature of men in the foregoing note, we may add some remarks about their unusual strength. That of Samson (who is not said to have exceeded other men in stature, as he did in strength) is well known. So of old, Hector, Diomedes, Hercules, and Ajax, are famed; and since them many others; for which I shall seek no farther than the before-commended Hakewill, who, by his great and curious learning, hath often most of the examples that are to be met with, on all his subjects, he undertakes. Of the after-ages he names C. Marius, Maximinus, Aurelian, Scanderbeg, Barbesin, Tamerlane, Ziska, and Hunniades. Anno 1529, Klunher, provost of the great church at Misnia, carried a pipe of wine out of the cellar, and laid it ni the

Locks and doors might perhaps have been made of sufficient strength to have barricaded our houses; and walls and ramparts might perhaps have been made strong enough to have fenced our cities. But these things could not have been without a great and inconvenient expence of room, materials, and such necessaries, as such vast structures and uses would have occasioned; more perhaps than the world could have afforded to all ages and places. But let us take the descant of a good naturalist and physician on the case (*e*). ‘Had man been a dwarf,’ said he, ‘he had scarce been a reasonable creature: for he must then have a jolt head; so there would not have been body and blood enough to supply his brain with spirits; or he must have had a small head answerable to his body, and so there would not have been brain enough for his business.—Or had the species of

cart. Mayolus saw one hold a marble pillar in his hand 3 feet long, and 1 foot diameter, which he tossed up in the air, and caught again as if it were a ball. Another at Mantua, and a little man, named Rodamas, could break a cable, etc. Ernando Burg fetched up stairs an ass laden with wood, and threw both into the fire. At Constantinople, An. 1582, one lifted a piece of wood, that twelve men could scarce raise; then lying along, he bare a stone that ten men could but just roll to him. G. of Fronsberg, baron of Mindleheim, could raise a man off his seat, with only his middle finger; stop a horse in his full career; and shove a cannon out of its place. Cardan saw a man dance with two men in his arms, two on his shoulders, and one on his neck. Patagona, captain of the Cossacks, could tear an horse-shoe; (and, if I mistake not, the same is reported of the late king Augustus of Poland.) A gigantic woman of the Netherlands could lift a barrel of Hamburg beer. Mr Carew had a tenant that could carry a butt's length, 6 bushels of wheaten meal (of 15 gallons measure) with the lubber the miller, of 24 years of age, on the top of it. And J. Roman, of the same county, could carry the carcase of an ox. Vide Hakewill, ib. p. 238.

‘Viros aliquot moderna memoria tam a mineralibus, quam aliis Suethiae et Gothiae provinciis adducere congruit, tanta fortitudine praeditos, ut quisque eorum in humeros sublevatum equum, vel bovem maximum, imo vas ferri 600, 800, 1000 librarum (quale et aliquae puellae levare possunt), ad plura stadia portaret.’ Ol. Mag. ubi supra.

(*e*) Grew's Cosmol. Sacr. book 1. chap. 5. sect. 25.

‘ mankind been gigantic, he could not have been so commodiously supplied with food : for there would not have been flesh enough of the best edible beasts to serve his turn. And if beasts had been made answerably bigger, there would not have been grass enough.’ And so he goeth on. And a little after, ‘ There would not have been the same use and discovery of his reason ; in that he would have done many things by mere strength, for which he is now put to invent innumerable engines.—Neither could he have used an horse, nor divers other creatures. But being of a middle bulk, he is fitted to manage and use them all. For,’ saith he, ‘ no other cause can be assigned, why a man was not made five or ten times bigger, but his relation to the rest of the universe.’ Thus far our curious author.

CH A P. V.

Of the STRUCTURE of the PARTS of Man's BODY.

HAVING thus taken a view of the posture, shape, and size of man's body, let us in this chapter survey the structure of its parts. But here we have so large a prospect, that it would be endless to proceed upon particulars. It must suffice therefore to take notice, in general only, how artificially every part of our body is made. No botch, no blunder, no unnecessary apparatus, or, in other words, no signs of chance (a) ; but every thing curious, orderly, and

(a) It is manifestly an argument of design, that in the bodies of different animals, there is an agreement of the parts, so far as the occasions and offices agree ; but a difference of those, where there is a difference of these. In an human body are many parts agreeing with those of a dog, for instance ; but in his forehead, fingers, hands, instruments of speech, and many other parts, there are muscles, and other members which are not in a dog : and so contrariwise in a dog, which are not in a man. If the reader is

performed in the shortest and best method, and adapted to the most compendious use. What one part is there throughout the whole body, but what is composed of the fittest matter for that part; made of the most proper strength and texture; shaped in the completest form; and, in a word, accoutred with every thing necessary for its motion, office, nourishment, guard, and what not! What so commodious a structure and texture could have been given to the bones, for instance, to make them firm and strong, and withal light, as that which every bone in the body hath! Who could have shaped them so nicely to every use, and adapted them to every part, made them of such just lengths, given them such due sizes and shapes, channelled, hollowed, headed, lubricated, and every other thing ministering, in the best and most compendious manner, to their several places and uses! What a glorious collection and combination have we also of the most exquisite workmanship and contrivance in the eye, in the ear, in the hand (*b*), in the foot (*c*), in the lungs, and other parts already mentioned! What an abridgement of

minded to see what particular muscles are in a man, that are not in a dog, or in a dog, that are not in a human body, let him consult the curious and accurate anatomist, Dr Douglass's *Myogr. compar.*

(*b*) Galen having described the muscles, tendons, and other parts of the fingers, and their motions, cries out, 'Considera igitur etiam hic mirabilem Creatoris sapientiam!' *De Usu Part. l. i. c. 18.*

(*c*) And not only in the hand, but in his account of the foot, l. 3. he frequently takes notice of what he calls, 'Artem, providentiam, et sapientiam Conditoris.' As chap. 13. 'An igitur non æquum est hic quoque admirari providentiam Conditoris, quia utrumque usum efficere contrarium, exacte convenientes et consentientes invicem fabricatus est totius membri [tibiae] particulas?' And at the end of the chapter, 'Quod si omnia quae ipsarum sunt partium mente immutaverimus, neque invenerimus positionem aliam meliorem ea quam nunc sortita, sunt, neque figuram, neque magnitudinem, neque connexionem neque (ut paucis omnia complectar) aliud quidquam eorum, quae corporibus necessario insunt, perfectissimam pronuntiare oportet, et undique recte constitutam praesentem ejus constructionem.' The like also concludes chap. 15.

art, what a variety of uses (*d*) hath nature laid upon that one member the tongue, the grand instrument of taste, the faithful judge, the centinel, the watchman of all our nourishment, the artful modulator of our voice, the necessary servant of mastication, swallowing, sucking, and a great deal besides! But I must desist from proceeding upon particulars, finding I am fallen upon what I proposed to avoid.

And therefore, for a close of this chapter, I shall only add part of a letter I received from the before-commended very curious and ingenious physician, Dr. Tancred Robinson: 'What,' saith he, 'can possibly be better contrived for animal motion and life, than the quick circulation of the blood and fluids, which run out of sight in capillary vessels, and very minute ducts, without impediment, except in some diseases, being all directed to their peculiar glands and channels, for the different secretion, sensible and insensible; whereof the last is the far greatest in quantity and effects, as to health and sickness, acute distempers frequently arising from a diminution of transpiration, through the cutaneous chimneys, and some chronical ones, from an augmentation: whereas obstructions in the liver, pancreas, and other glands, may only cause a schirrus, a jaundice, an ague, a dropfy, or other slow diseases. So an increase of that secretion may accompany the general colliquations, as in fluxes, hectic sweats and coughs, diabetes, and other consumptions. What a mighty contrivance is there to preserve these due secretions from the blood, (on which life so much depends), by frequent attritions, and communications of the fluids in their passage through the heart, the lungs, and the whole system of the muscles.

(*d*) 'At enim opificis industrii maximum est indicium (quod admodum ante saepenumero jam diximus) iis quae ad alium usum fuerunt comparata, ad alias quoque utilitates abuti, neque laborare ut singulis utilitatibus singulas faciat proprias partes.' Galen. ubi supra, l. 9. c. 5.

‘ What maeanders and contortions of vessels in the
‘ organs of separation ! And what a concourse of elastic
‘ bodies from the air, to supply the springs, and
‘ continual motions of some parts, not only in sleep
‘ and rest, but in long violent exercises of the muscles !
‘ Whose force drives the fluids round in a
‘ wonderful rapid circulation through the minutest
‘ tubes, assisted by the constant pabulum of the atmosphere,
‘ and their own elastic fibres, which impress that velocity on the fluids.

‘ Now I have mentioned some uses of the air,
‘ in carrying on several functions in animal bodies ;
‘ I may add the share it hath in all the digestions of
‘ the solid and fluid parts. For when this system of
‘ air comes, by divine permittance, to be corrupted
‘ with poisonous, acrimonious steams, either from
‘ the earth, from merchandise, or infected bodies,
‘ what havock is made in all the operations of living
‘ creatures ? The parts gangrene, and mortify
‘ under carbuncles, and other tokens : indeed, the
‘ whole animal oeconomy is ruined ; of such importance
‘ is the air to all the parts of it.’ Thus my
learned friend.

C H A P. VI.

Of the PLACING the PARTS of Man's BODY.

IN this chapter I propose to consider the lodgement
of the curious parts of man's body, which is no less
admirable than the parts themselves, all set in
the most convenient places of the body, to minister
to their own several uses and purposes, and assist,
and mutually to help one another. Where could
those faithful watchmen, the eye, the ear, the tongue,
be so commodiously placed, as in the upper part of
the building ? Where could we, throughout the
body, find so proper a part to lodge four of the senses,

as in the head (*a*), near the brain (*b*), the common sensory, a place well guarded, and of little other use than to be a seat to those senses? And how could we lodge the fifth sense, that of touching, otherwise (*c*), than to disperse it to all parts of the body! Where could we plant the hand (*d*), but just where it is, to be ready at every turn, on all occasions of help and defence, of motion, action, and every of its useful services! Where could we set the legs and feet, but where they are, to bear up and handsomely to carry about the body! Where could we lodge the heart, to labour about the whole mass of blood, but in, or near the centre of the body (*e*)! Where could we find room for that noble engine to play freely in! Where could we so well guard it against external harms, as it is in that very place in which it is lodged and secured! Where could we more commodiously place, than in the thorax and belly, the useful viscera of those parts, so as not to swag and jog, and overfet the body, and yet to minister so harmoniously as they do, to all the several uses of concoction, sanguification, the separation of various ferments from the blood, for the great uses of nature, and to make discharges of what is useless, or would be burdensome or pernicious.

(*a*) 'Sensus, interpretes ac nuncii rerum, in capite tanquam in arce, mirifice ad usus necessarios et facti, et collocati sunt. Nam oculi, tanquam speculatores, altissimum locum obtinent; ex quo plurima conspicientes, fungantur suo munere. Et aures cum sonum recipere debeant, qui natura in sublime fertur; recte in illis corporum partibus collocatae sunt.' Cicero. de Nat. Deor. l. 2. c. 56. ubi plura de caeteris sensibus.

(*b*) Galen well observes, that the nerves ministering to motion, are hard and firm, to be less subject to injury; but those ministering to sense, are soft and tender; and that for this reason it is, that four of the five senses are lodged so near the brain, viz. partly to partake of the brain's softness and tenderness, and partly for the sake of the strong guard of the skull. Vide Gal. de Usu Part. l. 8. c. 5, 6.

(*c*) See book iv. chap. 6. note (*c*), p. 159.

(*d*) 'Quam vero aptas, quamque multarum artium ministras manus natura homini dedit?' The particulars of which, enumerated by him, see in Cic. ubi supra, c. 60.

(*e*) See book vi. chap. 5.

cious to the body (*f*)! How could we plant the curious and great variety of bones, and of muscles, of all sorts and sizes, necessary, as I have said, to the support, and every motion of the body! Where could we lodge all the arteries and veins, to convey nourishment; and the nerves, sensation throughout the body! Where, I say, could we lodge all these implements of the body, to perform their several offices! How could we secure and guard them so well, as in the very places, and in the self-same manner in which they are already placed in the body! And lastly, to name no more, what covering, what fence could we find out for the whole body, better than that of nature's own providing, the skin (*g*)! How could we shape it to, or brace it about every part better, either for convenience or ornament! What better texture could we give it, which although less obdurate, and firm than that of some other animal, yet is so much the more sensible of every touch, and more compliant with every motion? And being easily defensible by the power of man's reason and art, is therefore much the properest tegument for a reasonable creature.

C H A P. VII.

Of the PROVISION in Man's BODY against EVILS.

HAVING taken a transient view of the structure and lodgement of the parts of the human bodies; let us next consider the admirable provision that is made throughout man's body, to stave off

(*f*) ' Ut in aedificiis architecti avertunt ab oculis et naribus dominorum ea, quae profuentia necessario tetri essent aliquid habitura; sic natura res similes, scil. excrementa, procul amandavit a sensibus.' Cic. de Nat. Deor. l. 2. c. 56.

(*g*) Compare here Galen's observations De Usu part. l. 11. c. 15. Also l. 2. c. 6. See also Cowper, Anat. where in tab. 4. are very elegant cuts of the skin in divers parts of the body, drawn from microscopical views; as also of the papillae pyramidales, the sudoriferous glands, and vessels, the hairs, etc.

evils, and to discharge (*a*) them when befallen. For the prevention of evils, we may take the instances already given, of the situation of those faithful centinels, the eye, the ear, and tongue, in the superior part of the body, the better to descry dangers at a distance, and to call out presently for help. And how well situated is the hand to be a sure and ready guard to the body, as well as the faithful performer of most of its services! The brain, the nerves, the arteries, the heart (*b*), the lungs; and, in a word, all the principal parts, how well are they barricaded, either with strong bones, or deep lodgements in the flesh, or some such the wisest and fittest method, most agreeable to the office and action of the part? Besides which, for greater precaution, and a farther security, what an incomparable provision hath the infinite contriver of man's body made for the loss of, or any defect in, some of the parts we can least spare, by doubling them! By giving us two eyes, two ears, two hands, two kidneys, two lobes of the lungs, pairs of the nerves, and many ramifications of the arteries and veins in the fleshy parts, that there may not be a defect of nourishment of the parts, in cases of amputation, or wounds, or ruptures of any of the vessels.

And as man's body is admirably contrived, and made to prevent evils; so no less art and caution hath been used to get rid of them, when they do

(*a*) One of nature's most constant methods here, is by the glands, and the secretions made by them; the particulars of which being too long for these notes, I shall refer to the modern anatomists, who have written on these subjects; and indeed, who are the only men that have done it tolerably: particularly our learned doctors Cockburn, Keil, Morland, and others at home and abroad; an abridgement of whose opinions and observations, for the reader's ease, may be met with in Dr Harris's *Lex. Tech.* vol. 2 under the words Glands, and Animal Secretion.

(*b*) In man, and most other animals, the heart hath the guard of bones; but in the lamprey, which hath no bones, (no not so much as a back bone), 'the heart is very strangely secured, and lies immured, or capsulated in a cartilage, or gristly substance, which includes the heart, and its auricle, as the skull doth the brain in other animals.' Power's *Microsc. obs.* 22.

happen. When, by any misfortune, wounds or hurts do befall; or when, by our own wicked fooleries and vices, we pull down diseases and mischiefs upon ourselves, what emunctories (*c*), what admirable passages (*d*), are dispersed throughout the body; what incomparable methods doth nature take (*e*); what

(*c*) Here [from the pustules he observed in Monomotapa] were grounds to admire the contrivance of our blood, which, on some occasions, so soon as any thing destructive to the constitution of it comes into it, immediately by an intestine commotion, endeavoureth to thrust it forth, and is not only freed from the new guest; but sometimes what likewise may have lain lurking therein—for a great while. And from hence it comes to pass, that most parts of medicines, when duly administered, are not only sent out of the body themselves; but likewise great quantities of morbid matter: as in salivation, etc. Dr Sloane's Voy. to Jamaica, p. 25.

(*d*) Valsalva discovered some passages into the region of the ear-drum, of mighty use, among others, to make discharges of bruises, imposthumes, or any purulent, or morbid matter from the brain, and parts of the head. Of which he gives two examples: One a person, who, from a blow on his head, had dismal pains therein, grew speechless, and lay under an absolute suppression and decay of his strength; but found certain relief, whenever he had a flux of blood, or purulent matter out of his ear; which after his death Valsalva discovered was through those passages.

The other was an apoplethical case, wherein he found a large quantity of extravasated blood, making way from the ventricles of the brain, through those same passages. Valsal. de Aure hum. c. 2. sect. 14. and c. 5. sect. 8.

(*e*) Hippocrates, Lib. de Alimentis, takes notice of the sagacity of nature, in finding out methods and passages for the discharging things offensive to the body, of which the late learned and ingenious bishop of Clogher, in Ireland, (Boyle), gave this remarkable instance, to my very curious and ingenious neighbour and friend, D'Acre Barret, Esq; viz. that in the plague-year, a gentleman at the university had a large plague sore gathered under his arm, which, when they expected it would have broken, discharged itself by a more than ordinary large and foetid stool; the sore having no other vent for it, and immediately becoming sound and well thereon.

Like to which is the story of Jos. Læzoni, of a soldier of thirty-five years of age, who had a swelling in his right hip, accompanied with great pain, etc. By the use of emollient medicines, having ripened the sore, the surgeon intended the next day to have opened it; but about midnight, the patient having great provocations to stool, disburdened himself three times;

vigorous efforts is she enabled to make, to discharge the peccant humour, to correct the morbid matter; and, in a word, to set all things right again? But here we had best take the advice of a learned physician in the case: 'The body,' saith he, 'is so contrived, as to be well enough secured against the mutations in the air, and the lesser errors we daily run upon; did we not in the excesses of eating, drinking, thinking, loving, hating, or some other folly, let in the enemy, or lay violent hands upon ourselves. Nor is the body fitted only to prevent, but also to cure, or mitigate diseases, when by these follies brought upon us. In most wounds, if kept clean, and from the air,—the flesh will glue together with its own native balm. Broken bones are cemented with the callus, which themselves help to make.' And so he goes on with ample instances in this matter, too many to be here specified (*f*). Among which he instanceth in the distempers of our bodies, shewing, that even many of

immediately upon which, both the tumour and pain ceased, and thereby disappointed the surgeon's intentions. Ephem. Germ. Anno 1690, obs. 49. More such instances we find of Mr Tonge's, in Phil. Trans. No 323. But indeed there are so many examples of this nature, in our Phil. Trans. in Ephem. German. Tho. Bartholine, Rhodius, Sennertus, Hildanus, etc. that it would be endless to recount them. Some have swallowed knives, bodkins, needles, and pins, bullets, pebbles, and twenty other such things as could not find a passage the ordinary way, but have met with an exit through the bladder, or some other way of nature's own providing. But passing over many particulars, I shall only give one instance more, because it may be a good caution to some persons, that these papers may probably fall into the hands of; and that is, the danger of swallowing plumb-stones, prune-stones, etc. Sir Francis Butler's lady had many prune-stones that made way through an abscess near her navel, Phil. Trans. No. 265, where are many other such like examples. More also may be found in No. 282, 304, etc. And at this day a young man, living not far off me, laboureth under very troublesome and dangerous symptoms, from the stones of spleen and bullace, which he swallowed eight or ten years ago.

(*f*) Grew's Cosmol. sect. 28. 29.

them are highly serviceable to the discharge of malignant humours, and preventing greater evils.

And no less kind than admirable is this contrivance of man's body, that even its distempers should many times be its cure (*g*); that when the enemy lies lurking within to destroy us, there should be such a reluctance, and all nature excited with its utmost vigour to expel him thence. To which purpose, even pain itself is of great and excellent use, not only in giving us notice of the presence of the enemy, but by exciting us to use our utmost diligence and skill to root out so troublesome and destructive a companion.

(*g*) 'Nor are diseases themselves useless: for the blood in a fever, if well governed, like wine upon the fret, dischargeth itself of all heterogeneous mixtures; and nature, the disease and remedies, clean all the rooms of the house; whereby that which threatens death, tends, in conclusion, to the prolonging of life.' Grew, *ubi supra*, sect. 52.

And as diseases minister sometimes to health; so to other good uses in the body, such as quickening the senses: of which take these instances relating to the hearing and sight.

'A very ingenious physician falling into an odd kind of fever, had his sense of hearing thereby made so very nice and tender, that he very plainly heard soft whispers, that were made at a considerable distance off, and which were not in the least perceived by the by-standers, nor would have been by him before his sickness.'

'A gentleman of eminent parts and note, during a distemper he had in his eyes, had his organs of sight brought to be so tender, that both his friends and himself have assured me, that when he walked in the night, he could for a while plainly see and distinguish colours, as well as other objects, discernible by the eye, as was more than once tried.' Boyl.
deter. nat. of Effluv. chap. 4.

'Daniel Frazer—continued deaf and dumb from his birth, till the 17th year of his age——After his recovery from a fever, he perceived a motion in his brain, which was very uneasy to him; and afterwards he began to hear, and in process of time, to understand speech,' etc. *Vide Phil. Trans. No.*

C H A P. VIII.

Of the CONSENT between the PARTS of Man's BODY.

IT is an admirable provision the merciful Creator hath made for the good of man's body, by the consent and harmony between the parts thereof: of which let us take St Paul's description, in 1 Cor. xiii. 8. 'But now hath God set the members, every one of them in the body, as it hath pleased him.' And ver. 21. 'The eye cannot say unto the hand, I have no need of thee: nor again, the head to the feet, I have no need of you.' But such is the consent of all the parts, or, as the apostle wordeth it, 'God hath so tempered the body together, that the members should have the same care one for another,' ver. 25. 'So that whether one member suffer, all the members suffer with it; or one member be honoured, (or affected with any good), all the members rejoice [and sympathize] with it,' ver. 26.

This mutual accord, consent, and sympathy of the members, there is no reason to doubt (a), is made by the commerce of the nerves (b), and their artificial positions, and curious ramifications throughout the whole body, which is admirable and incomparable, and might deserve a place in this survey, as greatly and manifestly setting forth the wisdom and

(a) See book iv. chap. 8.

(b) 'Tria proposita ipsi naturae in nervorum distributione fuerunt. 1. Ut sensoriis instrumentis sensum impericerent. 2. Ut motoriis motum. 3. Ut omnibus aliis [partibus] darent ut quae, si dolorem adferrent, dignoscerent.' And afterwards 'Si quis in dissectionibus spectavit, consideravitque justene secus natura nervos non eadem mensura omnibus partibus distribuerit, sed aliis quidem liberalius, aliis vero parcius, eadem cum Hippocrate, velit nolit, de natura omnino pronuntiabile quod ea scilicet sagax, justa, artificiosa, animaliumque provisum est.' Galen. de usu Part. l. 5. c. 9.

benignity of the great Creator; but that to give a description thereof from the origin of the nerves, in the brain, the cerebellum and spine, and so through every part of the body, would be tedious, and intrench too much upon the anatomist's province: and therefore one instance shall suffice for a sample of the whole; and that shall be, (what was promised before) (c), the great sympathy occasioned by the fifth pair of nerves; which I chuse to instance in, rather than the par vagum, or any other of the nerves; because although we may have less variety of noble contrivance and art, than in that pair; yet we shall find enough for our purpose, and which may be dispatched in fewer words. Now, this fifth conjugation of nerves is branched to the ball, the muscles, and glands of the eye; to the ear; to the jaws, the gums, and teeth; to the muscles of the lips (d); to the tonsils, the palate, the tongue, and the parts of the mouth; to the praecordia also, in some measure, by inosculating with one of its nerves; and lastly, to the muscles of the face, particularly the cheeks, whose sanguiferous vessels it twists about.

From hence it comes to pass, that there is a great consent and sympathy (e) between these parts; so that a gustable thing seen or smelt, excites the appetite, and affects the glands and parts of the mouth; that a thing seen or heard, that is shameful, affects the cheeks with modest blushes; but on the contrary, if

(c) Book iv. chap. 5.

(d) Dr Willis gives the reason, 'Cur mutua amasiorum oscula labiis impressa, tum praecordia, tum genitalia afficiendo, amorem ac libidinem tam facile irritant,' to be from the consent of those parts, by the branches of this fifth pair. Nerv. Descr. c. 22.

And Dr Sachs judges it to be from the consent of the 'labia oris cum labiis uteri,' that in April 1699, a certain breeding lady, being affrighted with seeing one that had scabby lips, which they told her were occasioned by a pestilential fever, had such like pustules broke out in the labia uteri. Ephem. Germ. T. 1. obs. 20.

(e) Consult Willis, ubi supra.

it pleases and tickles the fancy, that it affects the praecordia and muscles of the mouth and face with laughter; but a thing causing sadness and melancholy, doth accordingly exert itself upon the praecordia, and demonstrate itself by causing the glands of the eyes to emit tears (*f*), and the muscles of the face to put on the sorrowful aspect of crying. Hence also that torvous sour look produced by anger and hatred; and that gay and pleasing countenance accompanying love and hope. And in short, it is by means of this communication of the nerves, that whatever affects the soul is demonstrated whether we will or no, by a consentaneous disposition of the praecordia within, and a suitable configuration of the muscles and parts of the face without. And an admirable contrivance of the great God of nature this is; that as a face is given to man, and, as Pliny saith, (*g*), to man alone of all creatures; so it should be, as he observes, ‘the index of sorrow and chearfulness, of compassion and severity. In its ascending part is the brow, and therein a part of the mind too. Therewith we deny, therewith we consent. With this it is we shew our pride, which hath its source in another place; but here its seat: in the heart it hath its birth; but here it abides and dwells; and that because it could find no other part throughout the body higher, or more craggy (*h*), where it might reside alone.’

Thus I have dispatched what I shall remark concerning the soul and body of man. There are divers other things, which well deserve a place in this survey; and those that I have taken notice of, deserved to have been enlarged upon: but what hath been

(*f*) Tears serve not only to moisten the eye, to clean and brighten the cornea, and to express our grief; but also to alleviate it, according to that of Ulysses to Andromache, in Seneca's Troas, ver. 762.

Tempus moramque dabimus, arbitrio tuo
Implere lacrymis: Fletus aerumnas levat.

(*g*) Plin. Nat. Hist. l. 11. c. 37.

(*h*) ‘Nihil altius simul abruptiusque invenit.’

said may suffice for a taste and sample of this admirable piece of God's handy-work; at least serve as a supplement to what others have said before me. For which reason I have endeavoured to say as little wittingly as I could, of what they have taken notice of, except where the thread of my discourse laid a necessity upon me.

C H A P. IX.

Of the VARIETY of Mens FACES, VOICES, and HAND-WRITING.

HERE I would have put an end to my observations relating to man; but that there are three things so expressly declaring the divine management and concurrence, that I shall but just mention them, although taken notice of more amply by others; and that is, the great variety throughout the world, of mens faces (*a*), voices (*b*), and hand-writing. Had man's body been made according to any

(*a*) If the reader hath a mind to see examples of mens likeness, he may consult Valer. Maximus, l. 9. c. 14. concerning the likeness of Pompey the great, and Vibius, and Publicius Libertinus; as also of Pompey the father, who got the name of Coquus, he being like Menogenes the cook; with divers others.

(*b*) As the difference of tone makes a difference between every man's voice, of the same country, yea, family, so a different dialect and pronounciation differs persons of divers countries, yea, persons of one and the same country, speaking the same language: thus in Greece, there were the Ionic, Doric, Attic, and Eolic dialects. So in Great Britain, besides the grand diversity of English and Scots, the different counties vary very much in the pronounciation, accent, and tone, although all one and the same language. And the way of the Gileadites proving the Ephraimites, Judges xii. 6 by the pronounciation of Shibboleth, with a Schin, or Sibboleth with a Samech, is well known. So a Lapide saith, the Flemings prove whether a man be a Frenchman or not, by bidding him pronounce Acht en tachtenticht; which they pronounce, Act en tactentick, by reason they cannot pronounce the aspirate H.

of the atheistical schemes, or any other method than that of the infinite Lord of the world, this wise variety would never have been; but mens faces would have been cast in the same, or not a very different mould; their organs of speech would have sounded the same, or not so great a variety of notes; and the same structure of muscles and nerves would have given the hand the same direction in writing. And in this case, what confusion, what disturbance, what mischiefs, would the world eternally have lain under! No security could have been to our persons; no certainty, no enjoyment of our possessions (c); no justice between man and man; no distinction between good and bad, between friends and foes, between father and child, husband and wife, male or female; but all would have been turned topsyturvey, by being exposed to the malice of the envious and ill-natured, to the fraud and violence of knaves and robbers, to the forgeries of the crafty cheat, to the lusts of the effeminate and debauched, and what not! Our courts of justice (d) can abundantly testify the dire effects of mistaking mens faces, of counterfeiting their hands, and forging writings. But now, as the infinitely wise Creator and Ruler hath ordered the matter, every man's face can distinguish him in the light, and his voice in the dark; his hand-writing can speak for him though absent, and be his witness, and secure his contracts in future generations. A

(c) 'Regi Antiocho unus ex aequalibus—nomine Artemon, perquam similis fuisse traditur. Quem Laodice, uxor Antiochi, interfecto viro, dissimulandi sceleris gratia, in lectulo perinde quasi ipsum regem acrum collocavit. Admissumque universum populum, et sermone ejus et vultu consimili sefellit: credideruntque homines ab Antiocho moriente Laodicen et natos ejus sibi commendari.' Valer. Max. ib.

(d) 'Quid Trebellius Calca! quam asseveranter sese Clodium tulit! et quidem dum de bonis ejus contendit, in centumvirale judicium adeo favorabilis descendit, ut vix justis et aequis sententiis conternatio populi ullum relinqueret locum. In illa tamē quaestione neque calumniae petitoris, neque violentiae plebis judicantium religio cessit.' Val. Max. ib. c. 15.

manifest, as well as admirable indication of the divine superintendence and management (e).

(e) To the foregoing instances of divine management, with relation to the political state of man, I shall add another thing, that I confess hath always seemed to me somewhat odd, but very providential; and that is, the value that mankind, at least the civilized part of them, have in all ages put upon gems, and the purer finer metals, gold and silver; so as to think them equivalent unto, and exchange them for things of the greatest use for food, clothing, and all other necessities and conveniencies of life. Whereas those things themselves are of very little, if any use, in physic, food, building, or clothing, otherwise than for ornament, or to minister to luxury; as Suetonius tells us of Nero, who fished with a net gilt with gold, and shod his mules with silver; but his wife Poppaea shod her horses with gold. Vit. Ner. c. 30. Plin. Nat. Hist. l. 33. c. 11. So the same Suetonius tells us, Jul. Caesar lay in a bed of gold, and rode in a silver chariot. But Heliogabalus rode in one of gold, and had his close-stool-pans of the same metal. And Pliny saith, 'Vasa coquinaria ex argento Calvus orator fieri queritur.' Ibid. Neither are those precious things of greater use to the making of vessels and utensils, (unless some little niceties and curiosities), by means of their beauty, imperdibility, and ductility. Of which last, the great Mr Boyle hath, among others, these two instances, in his Essay about the Subtily of Effluvioms, chap. 2. 'Silver, whose ductility and tractility are very much inferior to those of gold, was by my procuring, drawn out to so slender a wire, that—a single grain of it amounted to twenty-seven feet.' As to gold, he demonstrates it possible to extend an ounce thereof to reach to 777600 feet, or 155 miles and an half, yea, to an incredibly greater length.

And as to gems, the very stories that are told of their prodigious virtues, are an argument, that they have very little, or none, more than other hard stones. That a diamond should discover whether a woman be true or false to her husband's bed; cause love between man and wife; secure against witchcraft, plague, and poisons; that the ruby should dispose to chearfulness, cause pleasant dreams, change its colour against a misfortune befalling, etc.; that the sapphire should grow foul, and lose its beauty, when worn by one that is lecherous; that the emerald should fly to pieces, if it touch the skin of any unchaste person in the act of uncleanness; that the chrysolite should lose its colour, if poison be on the table, and recover it again when the poison is off; and, to name no more, that the turcoise, and the same is said of a gold ring, should strike the hour when hung over a drinking glass, and much more to the same purpose: all these, and many other such fabulous stories, I say, of gems, are great arguments, that their virtue is equivalent to their value. Of these, and other virtues, consult Wormius, in his Musaeum, l. 1. sect. 2. c. 17, etc.

C H A P. X.

The CONCLUSION of the SURVEY of MAN.

AND now having taken a view of man, and finding every part of him, every thing relating to him contrived, and made in the very best manner; his body fitted up with the utmost foresight, art, and care; and his body, (to the great honour, privilege, and benefit of man), possessed by a divine part, the soul, a substance made, as it were, on purpose to contemplate the works of GOD, and glorify the great Creator; and since this soul can discern, think, reason, and speak; what can we conclude upon the whole matter, but that we lie under all the obligations of duty and gratitude, to be thankful and obedient to, and to set forth the glories of our great Creator, and noble Benefactor! And what ungrateful wretches are we, how much worse than the poor irrationals, if we do not employ the utmost power of our tongue, and all our members, and all the faculties of our souls, in the praises of God! But above all, should we, who have the benefit of those glorious acts and contrivances of the Creator, be such wicked, such base, such worse than brutal fools, to deny the Creator (a), in

But as to gems changing their colour, there may be somewhat of truth in that, particularly in the turcoise last mentioned. Mr Boyle observed the spots in a turcoise, to shift their place from one part to another, by gentle degrees. So did the cloud in an agate-handle of a knife. A diamond he wore on his finger, he observed to be more illustrious at some times than others; which a curious lady told him she had also observed in hers. So likewise a rich ruby did the same. *Boyl. of Absol. Rest in Bodies.*

(a) It was a pious, as well as just conclusion, the ingenious Laurence Bellini. makes of his *Opusculum de Motu Cordis*, in these words: 'De motu cordis isthaec. Quae equidem omnia si a rudi intelligentia hominis tantum consilii, tantum ratiocinii,

some of his noblest works? Should we so abuse our reason, yea, our very senses; should we be so besotted by the devil, and blinded by our lusts, as to attribute one of the best contrived pieces of workmanship to blind chance, or unguided matter and motion, or any other such sottish, wretched, atheistical stuff; which we never saw, nor ever heard made any one being (*b*) in any age since the creation? No, no! But, like wise and unprejudiced men, let us with David say, Psalm cxxxix. 14. with which I conclude,

‘tantum peritiae mille rerum, tantum scientiarum exigunt, ad hoc, ut inveniantur, seu ad hoc, ut percipiantur postquam facta sunt; illum, cujus opera fabrefacta sunt haec singula, tam vani erimus atque inanes, ut existimemus esse consilii impotem, rationis expertem, imperitum, aut ignarum omnium rerum? Quantum ad me attinet, nolim esse rationis compos, si tantum insudandum mihi esset ad consequendum intelligentiam earum rerum, quas fabrefaceret nescio quae vis, quae nihil intelligeret eorum quae fabrefaceret; mihi etenim viderer esse vile quiddam, atque ridiculum, qui vellem totam aetatem meam, sanitatem, et quietem, quicquid laetitiarum, quicquid commodorum; non divitias, non dignitates; non poenas etiam, et vitam ipsam, ut gloriari possem postremo invenisse unum, aut alterum, et fortasse me invenisse quidem ex iis innumeris, quae produxisset, nescio quis ille, qui sine labore, sine cura, nihil cogitans, nihil cognoscens, non unam aut alteram rem, neque dubie sed certo produxisset innumeras innumerabiles rerum in hoc tam immenso spatio corporum, ex quibus totus mundus compingitur. Ah Deum immortalem! Video praesens numen tuum in hisce tam prodigiosis generationis initiis, et in altissima eorum contemplatione defixus, nescio quo oestro admirationis conciter, et quasi divinae furens cohibere me minime possum quin exclamem.

‘Magnus Dominus! Magnus fabricator hominum Deus! Magnus atque admirabilis Conditor rerum Deus, quam magnus es!’
Bellin. de Mot. Cord. fin.

(*b*) ‘Hoc [i. e. mundum effici ornatissimum, et pulcherrimum ex concursione fortuita] qui existimat fieri potuisse, non intelligo cur non idem putet, si innumerabiles unus et viginti formae literarum, vel aureae, vel qualeslibet, aliquo conjiciantur, posse ex his in terram excussis annales Ennii ut deinceps legi possint, effici, etc.—Quod si mundum efficere potest concursus atomorum, cur porticum, cur templum, cur domum, cur urbem non potest? Quae sunt minus operosa, et multo quidem faciliora.’ Cic. de Nat. Deor. l. 2. c. 37.

‘ I will praise thee, for I am fearfully and wonder-
 ‘ fully made; marvellous are thy works, and that my
 ‘ soul knoweth right well.’

Having thus made what (considering the copious-
 ness and excellence of the subject) may be called a
 very brief survey of man, and seen such admirable
 marks of the divine design and art; let us next take
 a transient view of the other inferior creatures; and
 begin with quadrupeds.

B O O K VI.

A SURVEY of QUADRUPEDS.

C H A P. I.

Of their PRONE POSTURE.

IN taking a view of this part of the animal world,
 so far as the structure of their bodies is conform-
 able to that of man, I shall pass them by, and
 only take notice of some peculiarities in them, which
 are plain indications of design, and the divine super-
 intendence and management. And, 1. The most
 visible apparent variation is the prone posture of their
 body: concerning which I shall take notice only of
 two things, the parts ministering thereto, and the
 use and benefit thereof.

I. As for the parts, it is observable, that in all
 these creatures, the legs are made exactly conform-
 able to this posture, as those in man are to his erect
 posture: and what is farther observable also, is, that
 the legs and feet are always admirably suited to the

motion and exercises of each animal: in some they are made for strength only, to support a vast, unwieldy body (*a*); in others they are made for agility and swiftness (*b*); in some they are made for only walking and running, in others for that, and swimming too (*c*); in others for walking and digging (*d*); and in others for walking and flying (*e*): in some they are made more lask and weak, for the plainer lands; in others rigid, stiff, and less flexible (*f*),

(*a*) The elephant being a creature of prodigious weight, the largest of all animals, Pliny saith, hath its legs accordingly made of an immense strength, like pillars, rather than legs.

(*b*) Deer, hares, and other creatures, remarkable for swiftness, have their legs accordingly slender, but withal strong, and every way adapted to their swiftness.

(*c*) Thus the feet of the otter are made, the toes being all conjoined with membranes, as the feet of geese and ducks are. And in swimming it is observable, that when the foot goes forward in the water, the toes are close; but when backward, they are spread out, whereby they more forcibly strike the water, and drive themselves forward. The same may be observed also in ducks and geese, etc.

Of the castor or beaver, the French academists say, 'The structure of the feet was very extraordinary, and sufficiently demonstrated, that nature hath designed this animal to live in the water, as well as upon land. For although it had four feet, like terrestrial animals, yet the hindmost seemed more proper to swim than walk with, the five toes of which they were composed, being joined together like those of a goose by a membrane, which serves this animal to swim with. But the fore ones were made otherwise; for there was no membrane which held those toes joined together; and this was requisite, for the conveniency of this animal, which useth them as hands like a squirrel, when he eats.' *Memoirs for a Natural History of Animals*, p. 84.

(*d*) The moles feet are a remarkable instance.

(*e*) The wings of the bat are a prodigious deviation from nature's ordinary way. So it is in the Virginian squirrel, whose skin is extended between the fore-legs and its body.

(*f*) Of the legs of the elk, the French academists say, 'Although some authors report, that there are elks in Muscovia, whose legs are jointless; there is great probability, that this opinion is founded on what is reported of those elks of Muscovia, as well as of Caesar's Alce, and Pliny's Machlis, that they have legs so stiff and inflexible, that they do run on ice without slipping; which is a way that is reported that they have to save themselves from the wolves,' etc. *Ibid.* p. 108.

for traversing the ice, and dangerous precipices of the high mountains (*g*); in some they are shod with rough and hard hoofs, some whole, some cleft; in others with only a callous skin. In which latter, it is observable that the feet are composed of toes, some short for bare going; some long to supply the place of a hand (*h*); some armed with long and strong talons to catch, hold, and tear the prey; some fenced only with short nails, to confirm the steps in running and walking.

II. As the posture of man's body is the fittest for a rational animal, so is the prone posture of quadrupeds, the most useful and beneficial to themselves, as also most serviceable to man. For they are hereby better made for their gathering their food, to pursue their prey, to leap, to climb, to swim, to guard themselves against their enemies; and, in a word, to do whatever may be of principal use to themselves; as also they are hereby rendered more useful and serviceable to man for carrying his burdens, for tilling his ground; yea, even for his sports and diversions.

And now I might here add a survey of the excellent contrivance of the parts ministering to this posture of the four-footed animals, the admirable structure of the bones (*i*), the joints and muscles, their

(*g*) The common tame goat (whose habitation is generally on mountains and rocks, and who delighteth to walk on the tops of pales, houses, etc. and to take great and seemingly dangerous leaps) I have observed, hath the joints of the legs very stiff and strong, the hoof hollow underneath, and its edges sharp. The like, I doubt not, is to be found in the wild goat, considering what Dr Scheuchzer hath said of its climbing the most dangerous craggs of the Alps, and the manner of their hunting it. Vide Iter. Alpin. 3. p. 9.

(*h*) Thus in apes and monkeys, in the beaver before, and divers others.

(*i*) It is a singular provision nature hath made for the strength of the lion, if that be true, which Galen saith is reported of its bones being not hollow, as in other animals, but solid; which report he thus far confirms, that most of the bones are so; and that those in the legs, and some other parts, have only a small

various sizes and strength; their commodious lodgement and situation, the nice aequipoise of the body, with a great deal more to the same purpose. But I should be tedious to insist minutely upon such particulars; and besides, I have given a touch upon these kind of things, when I spake of man.

Passing by therefore many things of this kind, that might deserve remark, I shall only consider some of the parts of quadrupeds, differing from what is found in man (*k*), and which are manifest works of design.

C H A P. II.

Of the HEADS of QUADRUPEDS.

IT is remarkable that, in man, the head is of one singular form; in the four-footed race, as various as their species. In some, square and large, suitable to their slow motion, food, and abode; in others less, slender, and sharp, agreeable to their swifter motion, or to make their way to their food (*a*), or habitation under ground (*b*). But passing by a great

and obscure cavity in them. Vide Galen. de usu Part. I. 11. c. 18.

(*k*) 'These sorts of differences in the mechanism of animals, upon the score of the position of their bodies, occur so often, that it would be no mean service to anatomy—if any one would give us a history of those variations of the parts of animals, which spring from the different postures of their bodies.' Drake Anat. vol. 1. book 1. chap. 17.

(*a*) Thus swine, for instance, who dig in the earth for roots, and other food, have their neck, and all parts of their head very well adapted to that service. Their neck short, brawny and strong; their eyes set pretty high out of the way; their snout long; their nose callous and strong; and their sense of smelling very accurate, to hunt out and distinguish their food in mud, under ground, and other the like places where it lies concealed.

(*b*) What hath been said of swine, is no less, rather more remarkable in the mole, whose neck, nose, eyes, and ears, are all fitted, in the nicest manner, to its subterraneous way of life.

many observations that might be made of this kind, I shall stop a little at the brain, as the most considerable part of the body, being the great instrument of life and motion in quadrupeds, as it is in man of that, as also in all probability the chief seat of his immortal soul. And accordingly it is a remarkable difference, that in man the brain is large, affording substance and room for so noble a guest; whereas in quadrupeds, it is but small. And another thing, no less remarkable, is the situation of the cerebrum and cerebellum, or the greater and lesser brain, which I shall give in the words of one of the most exact anatomists we have of that part (c): ‘Since, saith he, God hath given to man a lofty countenance, to behold the heavens, and hath also seated an immortal soul in the brain, capable of the contemplation of heavenly things; therefore, as his face is erect, so the brain is set in an higher place, namely, above the cerebellum, and all the sensories. But in brutes, whose face is prone towards the earth, and whose brain is incapable of speculation, the cerebellum, (whose business it is to minister to the actions and functions of the praecordia, the principal office in those creatures), in them is situated in the higher place, and the cerebrum lower. Also some of the organs of sense, as the ears and eyes, are placed, if not above the cerebrum, yet at least equal thereunto.’

Another convenience in this position of the cerebrum and cerebellum, the last ingenious anatomist tells us is this (d). ‘In the head of man, saith he, the base of the brain and cerebell, yea, of the whole skull, is set parallel to the horizon; by which means there is the less danger of the two brains joggling, or slipping out of their place. But in

(c) Willis Cereb. Anat. cap. 6. ‘Cumque huic Deus os sublimè dederit,’ etc.

(d) Id. paulo post. ‘In capite humano cerebri et cerebelli,’ etc.

quadrupeds, whose head hangs down, the base of the skull makes a right angle with the horizon, by which means the brain is undermost, and the cerebell uppermost; so that one would be apt to imagine the cerebell should not be steady, but joggle out of its place.' To remedy which inconvenience, he tells us, 'And lest the frequent concussions of the cerebell should cause a fainting, or disorderly motion of the spirits, about the praecordia, therefore, by the artifice of nature, sufficient provision is made in all, by the dura meninx closely encompassing the cerebellum; besides which, it is, in some, guarded with a strong bony fence; and in others, as the hare, the coney, and such lesser quadrupeds, a part of the cerebell is on each side fenced with the os petrosum: so that by this double stay, its whole mass is firmly contained within the skull.'

Besides these peculiarities, I might take notice of divers other things no less remarkable, as the nictitating membrane of the eye (*e*), the different passages of the carotid arteries (*f*) through the skull, their

(*e*) See book iv. chap. 2. note (*ll*), p. 118.

(*f*) 'Arteria carotis aliquanto posterius in homine quam in alio quovis animali, calvariam ingreditur, scil. juxta illud foramen, per quod sinus lateralis in venam jugularem desiturus crano elabatur: nam in caeteris haec arteria sub extremitate seu processu acuto ossis petrosi, inter cranium emergit; verum in capite humano, eadem, ambage longiori circumducta (ut sanguinis torrens, priusquam ad cerebri oram appellit, fracto impetu, lenius et placidius fluat) prope specum ab ingressu sinus lateralis factum, calvariae basin attingit;—et in majorem cautelam, tunica insuper ascititia crassiore investitur.' And so he goes on to shew the conveniency of this guard the artery hath, and its passage to the brain; and then saith, 'Si hujusmodi conformationis ratio inquiritur, facile occurrit, in capite humano, ubi generosi affectus et magni animorum impetus ac ardores excitantur, sanguinis in cerebri oras appulsum debere esse liberum et expeditum, etc. Atque hoc quidem respectu differt homo a plerisque brutis, quibus, arteria in mille surculos divisa, ne sanguinem pleniore alveo, aut citatiore, quam par est, cursu, ad cerebrum evehat, plexus retiformes constituit, quibus nempe efficitur, ut sanguis tardo admodum, lenique et aequabili fere

branching into the rete mirabile (*g*), the different magnitude of the nates, and some other parts of the brain in beasts, quite different from what it is in man: but the touches already given, may be instances sufficient to prevent my being tedious in enlarging upon these admirable works of God.

CHAP. III.

Of the NECKS of QUADRUPEDS.

FROM the head pass we to the neck, no principal part of the body, but yet a good instance of the Creator's wisdom and design, inasmuch as in man it is short, agreeable to the erection of his body; but in the four-footed tribe it is long, answerable to the length of the legs (*a*), and in some of these long

* *fillicidio, in cerebrum illabatur.* And then he goes on to give a farther account of this artery, and the rete mirabile, in diverse creatures. Willis, *ibid.* c. 8.

(*g*) Galen thinks the rete mirabile is for concocting and elaborating the animal spirits, as the epididymides, [the convolutions, *κισσοειδὲς ἱλίκας*] are for elaborating the seed, *De usu Part. l. 9. c. 4.* This rete is much more conspicuous in beasts than in man: and, as Dr Willis well judges, serves, 1. To bridle the too rapid incursions of the blood into the brain of those creatures whose heads hang down much. 2. To separate some of the superfluous serous parts of the blood, and send them to the salivary glands, before the blood enters the brain of those animals, whose blood is naturally of a watery constitution. 3. To obviate any obstructions that may happen in the arteries, by giving a free passage through other vessels, when some are stopped.

In quadrupeds, as the carotid arteries are branched into the rete mirabile, for the bridling the too rapid current of blood into the brain; so the vertebral arteries are, near their entrance into the skull, bent into an acuter angle than in man, which is a wise provision for the same purpose.

(*a*) It is very remarkable, that in all the species of quadrupeds this equality holds, except only the elephant; and that there should be a sufficient special provision made for that creature, by its proboscis or trunk. A member so admirably contrived, so curiously wrought, and with so great agility and readiness applied to that unwieldy creature to all its several occasions, that I take

(b)
(c)

and less strong, serving to carry the mouth to the ground; in others shorter, brawny, and strong, serving to dig, and heave up great burdens (*b*).

But that which deserves especial remark is, that peculiar provision made in the necks of all, or most granivorous quadrupeds, for the perpetual holding down their heads in gathering their food, by that strong, tendinous, and insensible aponeurosis or ligamen (*c*), braced from the head to the middle of the back. By which means the head, although heavy, may be long held down without any labour, pain, or uneasiness to the muscles of the neck, that would otherwise be wearied by being so long put upon the stretch.

CHAP. IV.

Of the STOMACHS of QUADRUPEDS.

FROM the neck, let us descend to the Stomach, a part as of absolute necessity to the being and well-being of animals, so is in the several species of

to be a manifest instance of the Creator's workmanship. See its anatomy in Dr A. Moulen's Anat. of the Elephant, p. 33. As also in Mr Blair's account in Phil. Transf. No. 326.

'Aliorum ea est humilitas, ut cibum terrestrem rostris facile contingant. Quae autem altiora sunt, ut anseres, ut cygni, ut grues, ut cameli, adjuvantur proceritate collorum. Manus etiam data elephantis, qui propter magnitudinem corporis difficiles aditus habebant ad pastum.' Cic. de Nat. Deor. l. 2. c. 47.

'Quod iis animalibus quae pedes habent fissos in digitos, collum brevis sit factum, quam ut per ipsum cibum ori admoveant: iis vero quae ungulas habent solidas, aut bifidas, longius, ut prona atque inclinantia pasci queant. Qui id etiam opus non sit artificis utilitatis memoris? Ad haec quod grues ac ciconiae, cum crura haberent longiora, ob eam causam rostrum etiam magnum, et collum longius habuerint. Pisces autem neque collum penitus habuere, utpote qui neque crura habent. Quo pacto non id etiam est admirandum?' Galen. de usu Part. II. c. 8.

(*b*) As in moles and swine, in chap. 2. note (*a*, *b*), p. 309.

(*c*) Called the white-leather, pack-wax, tax-wax, and fix-fax.

quadrupeds, sized, contrived, and made with the utmost variety and art (*a*). What artist, what being, but the infinite Conservator of the world, could so well adapt every food to all the several kinds of those grand devourers of it! Who could so well suit their stomachs to the reception and digestion thereof; one kind of stomach to the carnivorous, another to the herbacious animals; one fitted to digest by bare mastication; and a whole set of stomachs in others, to digest with the help of rumination! Which last act, together with the apparatus for that service, is so peculiar, and withal so curious an artifice of nature, that it might justly deserve a more particular inquiry; but having formerly mentioned it (*b*), and lest I should be too tedious, I shall pass it by.

CHAP. V.

Of the HEARTS of QUADRUPEDS.

IN this part is a notable difference found between the heart of man and that of beasts; concerning the latter of which I might take notice of the remarkable conformation of the hearts of amphibious quadrupeds, and their difference from those of land-animals, some having but one ventricle (*a*), some

(*a*) The peculiar contrivance and make of the dromedary's or camel's stomach, is very remarkable, which I will give from the Parisian anatomists: 'At the top of the second [of the 4 ventricles] there were several square holes, which were the orifices of about 30 cavities, made like sacks placed between the two membranes, which do compose the substance of this ventricle. The view of these sacks made us to think that they might well be the reservatories, where Pliny saith, that camels do a long time keep the water, which they drink in great abundance. To supply the wants thereof in the dry deserts,' etc. Vide Memoirs, etc. Anat. of Dromedary, p. 39. See also Peyer. Merycol, l. 2. c. 3.

(*b*) Book iv. chap. 11.

(*a*) Frogs are generally thought to have but one ventricle in their hearts.

three (*b*), and some but two, like land animals, but then the foramen ovale therewith (*c*). All which may be justly esteemed as wonderful, as they are excellent provisions for the manner of those animals living. But I shall content myself with bare hints of these things, and speak only of two peculiars more, and that but briefly.

One is, the situation of the heart, which in beasts is near the middle of the whole body; in man, nearer the head (*d*). The reasons of which I shall give from one of the most curious anatomists of that part (*e*). 'Seeing,' saith he, 'the trajection and distribution of the blood depends wholly on the systole of the heart, and that its liquor is not driven of its own nature so readily into the upper parts as into vessels even with it, or downwards into those under it: if the situation of the heart had been farther from the head, it must needs either have been made stronger, to cast out its liquor with greater force; or else the head would want its due propor-

(*b*) The tortoise hath three ventricles, as the Parisian academists in their Memoirs affirm. 'Besides those two ventricles [before spoken of] which were in the hinder part of the heart, which faceth the spine, there was, say they, a third in the fore-part, inclining a little towards the right side,' etc. Memoirs, etc. p. 259. But Mr Buffiere charges this as a mistake in those ingenious gentlemen, and asserts there is but one ventricle in the tortoise's heart. See his description of the heart of the land-tortoise, in Philos. Transf. No. 328.

(*c*) The sea-calf is said by the French academists, to have this provision, and their account of it is this: 'Its heart was round and flat. Its ventricles appeared very large, and its auricles small.——Underneath the great aperture, through which the trunk of the vena cava conveyed the blood into the right ventricle of the heart, there was another, which penetrated into the arteria venosa, and from thence into the left ventricle, and afterwards into the aorta. This hole, called the foramen ovale in the foetus, makes the anatomosis, by the means of which, the blood goes from the cava into the aorta, without passing through the lungs.' French Anat. p. 124.

(*d*) Τὴν τε Καρδίαν περὶ τὸ μίσον πλὴν ἐν Ἀνθρώπῳ, etc. Arist. Hist. An. l. 2. c. 17.

(*e*) Dr Lower de Corde, c. 1.

tion of blood. But in animals that have a longer neck, and which is extended towards their food as it were, the heart is seated as far from the other parts; and they find no inconvenience from it, because they feed with their head for the most part hanging down; and so the blood, as it hath farther to go to their head than in others, so it goes a plainer and often a steeper way (*f*).

The other peculiar matter is, the fastening, I formerly mentioned, which the cone of the pericardium hath in man to the diaphragm (*g*), whereas in all quadrupeds it is loose. By which means the motion of the midriff, in that necessary act of respiration, is assisted both in the upright posture of man, as also in the prone posture of quadrupeds (*h*), which would be hindered, or rendered more difficult, if the case was otherwise: 'Which must needs be the effect of wis-

(*f*) I might have mentioned another wise provision from the same author, which take in his own words: 'In vitulis et equis, imo plerisque aliis animalibus majoribus, non solas propagines a nervo sexti paris ut in homine, sed etiam plurimas a nervo intercostali, ubi recta cor transit, cor accedere, imo in parenchyma ejus dimitti: et hoc ideo a natura quasi subsidium brutis comparatum, ne capita quae terram prona spectant, non satis facile aut copiose spiritus animales impertirent.' Blasii Animal. par. 1. c. 4. ex Lowero, de corde.

(*g*) 'Diaphragmatis circulo nerveo firmiter adhaeret [pericardium] quod homini singulare; nam ab eo in canibus et similibus distat, item in aliis animalibus omnibus.' Bortholin. Anat. 1. 2. c. 5.

(*h*) 'Finalem causam quod attinet, — cum erectus sit hominis incessus atque figura, eoque facilius abdominis viscera suo pondere descendant, minore diaphragmatis nixu atque systole ad inspirationem opus est: porro, cum in expiratione pariter necessarium sit diaphragma relaxari, — cum capsula cordis omnino connectendum fuit, in homine, ne forte, quamdiu erectus incidit, ab hepatis, aliorumque viscerum appensorum pondere deorsum adeo deprimeretur, ut neque pulmo satis confidere, neque expiratio debito modo peragi potuerit. Quocirca in quadrupedibus, ubi abdominis viscera in ipsum diaphragma incumbunt, ipsumque in pectoris cavitatem suo pondere impellunt, istius partium accretio expirationi quidem inutilis, inspirationi autem debitam diaphragmatis tensionem impediendo, prorsus incommoda fuisset.' Lower, ib. p. 8.

dom and design, and that man was intended by nature to walk erect, not upon all-four, as quadrupeds do; to express it in the words of a great judge in such matters (i).

CHAP. VI.

Of the Difference between MAN and QUADRUPEDS in the Nervous Kind.

THERE is only one difference more between man and quadrupeds that I shall take notice of, and that is the nervous kind: and because it would be tedious to insist upon many particulars (a), I shall, for a sample, insist chiefly upon one, and that is, of nature's prodigious care for a due communication and correspondence between the head and heart of man, more than what is in the four-footed tribe. For this purpose, besides the correspondence those parts have by means of the nerves of the par vagum, common both to man and beast, there is a farther and more special communication and correspondence occasioned by the branches (b), of the intercostal pair, sent from the cervical plexus to the heart and praecordia. By which means the heart and brain of man have a mu-

(i) Dr Tyson's anatomy of the Orang-Outang, in Ray's Wisdom of God, p. 262.

(a) Among these, I might name the seat of the nerves proceeding from the medulla spinalis, which Dr Lower takes notice of. In beasts, whose spine is above the rest of the body, the nerves tend directly downwards; but in man, it being erect, the nerves spring out of the spine, not at right, but in oblique angles downwards, and pass also in the body the same way. Ib. p. 16.

(b) 'In plerisque brutis tantum hac via (i. e. by the par vagum) et vix omnino per ullos paris intercostalis nervos, aditus ad cor aut appendicem ejus patescit. Verum in homine, nervus intercostalis, praeter officia ejus in imo ventre huic cum caeteris animalibus communia, etiam ante pectoris claustra internuntii specialis loco est, qui cerebri et cordis sensa mutua ultra citraque refert.' Willis Nervor. Descrip. et Usus, c. 26.

tual and very intimate correspondence and concern with each other, more than is in other creatures; or as one of the most curious anatomists and observers of these things saith (c): ' Brutes are as it were machines made with a simpler and less operose apparatus, and endowed therefore with only one and the same kind of motion, are determined to do the same thing: whereas in man, there is a great variety of motions and actions. For by the commerce of the aforesaid cervical plexus (d), he saith, the conceptions of the brain presently affect the heart, and agitate its vessels and whole appendage, together with the diaphragm. From whence the alteration in the motion of the blood, the pulse, and respiration. So also, on the contrary, when any thing affects or alters the heart, those impressions are not only retorted to the brain by the same duct of the nerves, but also the blood itself, its course being once changed, flies to the brain with a different and unusual course, and there agitating the animal spirits with divers impulses, produceth various conceptions and thoughts in the mind.' And he tells us, ' That hence it was, that the ancient divines, and philosophers too, made the heart the seat of wisdom; and, certainly, says he, the works of wisdom and virtue do very much depend upon this commerce which is between the heart and brain: ' and so he goeth on with more to the same purpose. Upon the account of this intercostal commerce with the heart being wanting in brutes, there

(c) Id. ib. ' Dum hanc utriusque speciei differentiam perpendo succurrit animo; bruta esse velut machinas,' etc.

(d) That our great man was not mistaken, there is great reason to imagine, from what he observed in dissecting a fool. Besides the brain being but small, he saith, ' Praecipua autem discriminis nota quam inter illius et viri cordati partes advertimus haecce erat; nempe quod praedictus nervi intercostalis plexus quem cerebri et cordis internuncium et hominis proprium diximus, in stulto hoc valde exilis, et minori nervorum satellitum stipatus fuerit.' Ibid.

is another singularly careful and wise provision the infinite Creator hath made in them, and that is, that by reason both the par vagum, and the intercostal too, do not send their branches to the heart and its appendage in brutes; therefore, lest their heart should want a due proportion of nervous vessels, the par vagum sends more branches to their heart than to that of man. This, as it is a remarkable difference between rational and irrational creatures; so it is as remarkable an argument of the Creator's art and care; who although he hath denied brute-animals reason, and the nerves ministering thereto, yet hath another way supplied what is necessary to their life and state. But let us hear the same great author's descant upon the point (e). 'Inasmuch,' saith he, 'as beasts are void of discretion, and but little subject to various and different passions, therefore there was no need that the spirits, that were to be conveyed from the brain to the praecordia, should pass two different ways, namely, one for the service of the vital functions, and another for the reciprocal impressions of the affections; but it was sufficient that all their spirits, whatever use they were designed for, should be conveyed one and the same way.'

Here now in the nervous kind we have manifest acts of the Creator's design and wisdom, in this so manifest and distinct a provision for rational and irrational creatures; and that man was evidently intended to be the one, as the genus of quadrupeds was the other.

CH A P. VII.

The CONCLUSION.

AND now it is time to pause a while, and reflect upon the whole. And as from the con-

(e) Id. ib. chap. 29. 'In quantum bestiae prudentia carent, et variis diversisque passionibus,' etc.

siderations in the preceding book, we have especial reason to be thankful to our infinitely merciful Maker, for his no less kind than wonderful contrivances of our body; so we have reason, from this brief view I have taken of this last tribe of the creation, to acknowledge and admire the same Creator's work and contrivances in them. For we have here a large family of animals, in every particular respect, curiously contrived and made, for that especial posture, place, food, and office or business which they obtain in the world. So that if we consider their own particular happiness and good, or man's use and service; or if we view them throughout, and consider the parts wherein they agree with man, or those especially wherein they differ; we shall find all to be so far from being things fortuitous, undesigned, or any way accidental, that every thing is done for the best; all wisely contrived, and incomparably fitted up, and every way worthy of the great Creator. And he that will shut his eyes, and not see God (a) in these his works, even of the poor beasts of the earth, that will not say as Elihu hath it, Job xxxv. 10, 11. 'Where is God my maker, who teacheth us more than the beasts of the earth, and maketh us wiser than the fowls of the heaven?' of such an one we may use the psalmist's expression, Psalm xlix. 12. that 'he is like the beasts (b) that perish.'

(a) ——— Deum namque ire per omnes
Terrasque tractusque maris, coelumque profundum.
Hinc pecudes, armenta, viros, genus omne ferarum.

Virg. Geor. l. 4.

(b) 'Illos qui nullum omnino Deum esse dixerunt, non modo non philosophos, sed ne homines quidem fuisse dixerimus, qui, mutis simillimi, ex solo corpore constiterant, nihil videtis animo.' Lactant. l. 7. c. 9.

BOOK VII.

A SURVEY of BIRDS.

HAVING briefly, as well as I could, dispatched the tribe of quadrupeds; I shall next take a brief and transient view of the feathered tribe.

And here we have another large province to expatiate in, if we should descend to every thing wherein the workmanship of the Almighty appears. But I must contract my survey as much as may be; and shall therefore give only such hints and touches upon this curious family of animals, as may serve for samples of the rest of what might be observed.

CHAP. I.

Of the MOTION of BIRDS, and the PARTS ministering thereto.

AS this tribe hath a different motion from that of other animals, and an amphibious way of life; partly in the air, and partly on the land and waters; so is their body accordingly shaped, and all their parts incomparably fitted for that way of life and motion; as will be found by a cursory view of some of the particulars. And the

I. And most visible thing is the shape and make of their body, not thick and clumsy, but incomparably adapted to their flight: sharp before, to pierce and make way through the air, and then by gentle

degrees rising to its full bulk. To which we may add,

II. The neat position of the feathers throughout the body; not ruffled, or discomposed, or placed some this, some a contrary way, according to the method of chance; but all artificially placed (*a*), for facilitating the motion of the body, and its security at the same time, by way of clothing: and for that end, most of the feathers tend backward, and are laid over one another in exact and regular method, armed with warm and soft down next the body, and more strongly made, and curiously closed next the air and weather, to fence off the injuries thereof. To which purpose, as also for the more easy and nimble gliding of the body through the air, the provision nature hath made, and the instinct of these animals to preen and dress their feathers, is admirable; both in respect of their art and curiosity in doing it, and the oil-bag (*b*), glands, and whole apparatus for that service.

III. And now having said thus much relating to the body's motion, let us survey the grand instrument thereof, the wings: which, as they are principal parts, so are made with great skill, and placed in the most commodious point of the body (*c*), to give an exact equipoise in that subtle medium, the air.

(*a*) See before, book iv. chap. 12. note (*d*), p. 227.

(*b*) Mr Willoughby saith, there are two glands for the secretion of the unctuous matter in the oil-bag. And so they appear to be in geese. But upon examination, I find, that in most other birds, such at least as I have inquired into, there is only one gland; in which are divers little cells, ending in two or three larger cells, lying under the nipple of the oil-bag. This nipple is perforated, and being pressed, or drawn by the birds' bill, the head, emits the liquid oil, as it is in some birds, or thicker unctuous grease, as it is in others. The whole oil-bag is in its structure somewhat conformable to the breasts of such animals as afford milk.

(*c*) In all birds that fly much, or that have the most occasion for their wings, it is manifest that their wings are placed in the very best part, to balance their body in the air, and to give a swift a progression, as their wings and body are capable of: for

And here it is observable, with what incomparable curiosity every feather is made; the shaft exceeding strong, but hollow below, for strength and lightness sake; and above, not much less strong, and filled with a parenchyma or pith, both strong and light too. The vanes as nicely gauged on each side as made; broad on one side, and narrower on the other; both which incomparably minister to the progressive motion of the bird, as also to the union and closeness of the wing (*d*).

And no less exquisite is the textrine art of the plumage also (*e*); which is so curiously wrought, and

otherwise we should perceive them to reel, and fly unsteadily; as we see them to do, if we alter their equipoise, by cutting the end of one of the wings, or hanging a weight at any of the extreme parts of the body. But as for such birds as have as much occasion for swimming as flying, and whose wings are therefore set a little out of the centre of the body's gravity, see book iv. chap. 8. note (*g*), p. 177. and for such as have more occasion for flying than swimming, and whose legs are, for that reason, set more backward, and their wings more forward, see chap. 4. note (*k*), of this book.

(*d*) The wise Author of nature hath afforded an example of the great nicety in the formation of birds, by the nicety observed in the part no more considerable than the vanes of the flag-feathers of the wing. Among others, these two things are observable: 1. The edges of the exterior or narrow vanes bend downwards, but of the interior wider vanes upwards; by which means they catch, hold, and lie close to one another, when the wing is spread; so that not one feather may miss its full force and impulse upon the air. 2. A yet lesser nicety is observed, and that is, in the very turning the tips of the flag-feathers: the interior vanes being neatly sloped away to a point, towards the outward part of the wing; and the exterior vanes sloped towards the body, at least in many birds; and in the middle of the wing, the vanes being equal, are but little sloped. So that the wing, whether extended or shut, is as neatly sloped and formed, as if constantly trimmed with a pair of scissors.

(*e*) Since no exact account, that I know of, hath been given of the mechanism of the vanes, or webs of the feathers, my observation may not be unacceptable. The vane consists not of one continued membrane; because if once broken, it would hardly be reparable; but of many laminae, which are thin, stiff, and somewhat of the nature of a thin quill. Towards the shaft of the feather, (especially in the flag-feathers of the wing), those laminae are broad, etc. of a semicircular form; which serve for

so artificially interwoven, that it cannot be viewed without admiration, especially when the eye is assisted with glasses.

And as curiously made, so no less curiously are the feathers placed in the wings, exactly according to their several lengths and strength: the principals set for stay and strength, and these again well lined, faced, and guarded with the covers and secondary feathers, to keep the air from passing through, where-by the stronger impulses are made thereupon.

And lastly, to say no more of this part, that deserves more to be said of it, what an admirable apparatus is there of bones, very strong, but withal light and incomparably wrought! of joints, which open, shut, and every way move, according to the occasions either of extending it in flight, or withdrawing the wing again to the body! and of various muscles; among which the peculiar strength of the pectoral muscles deserves especial remark, by reason they are much stronger (*f*) in birds than in man, or any other animal, not made for flying!

strength, and for the closer shutting of the laminae to one another, when impulses are made upon the air. Towards the outward part of the vane, these laminae grow slender, and taper: on their under side they are thin and smooth, but their upper outer edge is parted into two hairy edges, each side having a different sort of hairs, laminated or broad at bottom, and slender and bearded above the other half. I have, as well as I could, represented the uppermost edge of one of these laminae in Fig. 18. with some of the hairs on each side, magnified with a microscope. These bearded bristles, or hairs, on one side the laminae, have strait beards, as in Fig. 19. those on the other side, have hooked beards on one side the slender part of the bristle, and strait ones on the other, as in Fig. 20. Both these sorts of bristles magnified, (only scattering, and not close). are represented as they grow upon the upper edge of the lamina S, t, in Fig. 18. And in the vane, the hooked beards of one lamina always lie next the strait beards of the next lamina; and by that means lock and hold each other; and by a pretty mechanism, brace the laminae close to one another. And if at any time the vane happens to be ruffled and discomposed, it can, by this pretty easy mechanism, be reduced and repaired. Vide book iv. chap. 12. note (*l*), p. 227.

(*f*) * *Pectorales musculi hominis flectentes humeros, parvi et*

IV. Next the wings, the tail is in flight considerable; greatly assisting in all ascents and descents in the air, as also serving to steady flight (*g*), by keeping the body upright in that subtle and yielding medium, by its readily turning and answering every vacillation of the body.

And now to the parts serving to flight, let us add the nice and complete manner of its performance; all done according to the strictest rules of mechanism (*b*). What rower on the waters, what artist on the land, what acutest mathematician could give a more agreeable and exact motion to the wings, than these untaught flying artists do to theirs! serving not only to bear their bodies up in the air, but also to waft them along therein, with a speedy progressive motion, as also to steer and turn them this way and that way, up and down, faster or slower, as their occasions require, or their pleasure leads them.

V. Next to the parts for flight, let us view the feet and legs ministering to their other motion: both made light, for easier transportation through the air;

parum cariosi sunt; non aequant soam aut 70am partem omnium musculorum hominis. E contra in avibus, pectorales musculi vastissimi sunt, et aequant, imo excedunt, et magis pendent, quam reliqui omnes musculi ejusdem avis simul sumpti. Borell. De Mot. Animal. vol. I. prop. 184.

Mr Willoughby, having made the like observation, hath this reflection on it. 'Whence, if it be possible for man to fly, it is thought by them who have curiously weighed and considered the matter, that he that would attempt such a thing with hopes of success, must so contrive and adapt his wings, that he may make use of his legs, and not his arms, in managing them: because the muscles of the legs are stronger, as he observes). Willough. Ornith. l. 1. c. 1. sect. 19.

(*g*) Mr Willoughby, Ray, and many others, imagine the principal use of the tail to be to steer and turn the body in the air as a rudder. But Borelli hath put it beyond all doubt, that this is the least use of it, and that it is chiefly to assist the bird in its ascents and descents in the air, and to obviate the vacillations of the body and wings. For, as for turning to this or that side, it is performed by the wings and inclinations of the body, and but very little by the help of the tail.

(*b*) See Borelli, ubi supra, prop. 182, etc.

and the former spread, some with membranes for swimming (*i*), some without, for steady going, for perching, for catching and holding of prey (*k*), or for hanging by the heels to gather their food (*l*), or to fix themselves in their place of retreat and safety. And the latter, namely, the legs, all curved for their easy perching, roosting, and rest, as also to help them upon their wings in taking their flight, and to be therein commodiously tucked up to the body, so as not to obstruct their flight. In some long, for wading and searching the waters; in some of a moderate length, answerable to their vulgar occasions; and in others as remarkably short, to answer their especial occasions and manner of life (*m*). To

(*i*) It is considerable in all water-fowl, how exactly their legs and feet correspond to that way of life. For either their legs are long, to enable them to wade in the waters: in which case, their legs are bare of feathers a good way above the knees, the more conveniently for this purpose. Their toes also are all broad; and in such as bear the name of mud-suckers, two of the toes are somewhat joined, that they may not easily sink in walking upon boggy places. And as for such as are whole-footed, or whose toes are webbed together, except some few, their legs are generally short, which is the most convenient size for swimming. And it is pretty enough to see how artificially they gather up their toes and feet when they withdraw their legs, or go to take their stroke; and as artificially again extend or open their whole foot, when they press upon, or drive themselves forward in the waters.

(*k*) Some of the characteristics of rapacious birds, are, 'have hooked, strong, and sharp-pointed beaks and talons, fitted for rapine, and tearing of flesh; and strong and brawny thighs, for striking down their prey.' Willoughby Ornith. l. 2. c. 1. Raii Synops. Av. Method. p. 1.

(*l*) Such birds as climb, particularly those of the wood-pecker kind, have, for this purpose, (as Mr Willoughby observes, l. 2. c. 4.) 1. Strong and muscular thighs. 2. Short legs and very strong. 3. Toes standing two forwards and two backwards. Their toes also are close joined together, that they may more strongly and firmly lay hold on the tree they climb upon. 4. All of them have a hard stiff tail, bending also downwards, on which they lean, and so bear up themselves in climbing.

(*m*) Swifts and swallows have remarkably short legs, especially the former, and their toes grasp any thing very strongly. And which is useful to them in building their nests, and other such

all these let us add the placing these last mentioned parts in the body. In all somewhat out of the centre of the body's gravity (*n*), but in such as swim, more than in others, for the better rowing their bodies through the waters, or to help them in their diving too (*o*).

CH A P. II.

Of the HEAD, STOMACH, and other Parts of BIRDS.

THUS having dispatched the parts principally concerned in the motion of the feathered tribe, let us proceed to some other parts not yet animadverted upon. And we will begin with the head, concerning which I have already taken notice of its shape for making way through the air; of the make of the bill, for gathering food, and other uses; the commodious situation of the eye; and I might add that of the ear too, which would be in the way, and

occasions as necessitate them to hang frequently by their heels. But there is far greater use of this structure of their legs and feet, if the reports be true of their hanging by the heels in great clusters, after the manner of bees, in mines and grottos, and on the rocks by the sea, all the winter. Of which latter, I remember the late learned Dr Fry told this story at the university, and confirmed it to me since, viz that an ancient fisherman, accounted an honest man, being near some rocks on the coast of Cornwall, saw at a very low ebb, a black list of something adhering to the rock, which when he came to examine, he found it was a great number of swallows, and, if I misremember not, of swifts also, hanging by the feet to one another, as bees do; which were covered commonly by the sea-waters, but revived in his warm hand, and by the fire. All this the fisherman himself assured the doctor of. Of this, see more, chap. 3. note (*d*), of this book.

(*n*) In birds that frequent not the waters, the wings are in the centre of gravity, when the bird lies along, as in flying; but when it stands or walks, the erection of the body throws the centre of gravity upon the thighs and feet.

(*o*) See chap. 4. note (*k*).

obstruct flight, if it was like that of most other animals: also I might say a great deal of the conformation of the brain (*a*), and of the parts therein wanting, and of others added, like to what is observable in fishes; whose posture in the waters resembles that of birds in the air (*b*), and both very different from man and beasts; and lastly, to hint at no more, I might survey the peculiar structure of the larynx (*c*), the tongue (*d*), the inner ear (*e*), and many matters

(*a*) 'Cerebra hominum et quadrupedum in plerisque similia existunt.—Capitibus volucrum et piscium contenta, ab utriusque prioribus longe diversa, tamen inter se, quoad præcipuas ἐγκεφάλαιες partes, symbola reperiuntur.' The particulars wherein the brains of birds and fishes agree with one another, and wherein they differ from the brain of man and beasts, see in the same justly famous author, Willis Cereb. Anat. c. 5.

(*b*) 'Circa bifurcationem asperae arteriae, elegans artificis habere agentis indicium detegitur ex avium comparatione cum quadrupedibus: cum vocis gratia in diversis avibus diversam musculorum fabricam bifurcationi asperae arteriae dederit, quorum nullum vestigium extat in homine et quadrupedibus mihi visis, ubi omnes vocis musculos capiti arteriae junxit. In aquila, etc. supra bifurcationem,' etc. Steno in Blas. Anat. Animal. p. 2. c. 4.

(*c*) The aspera arteria is very remarkable in the swan, which is thus described by T. Bartholin, viz. 'Aspera arteria admittit randaes latis structuræ. Nam pro colli longitudine deorsum oesophagi comes protenditur donec ad sternum perveniat, in quo ipsa capsulam se incurvo flexu insinuat et recondit, velut in tutulo loco et theca, moxque ad fundum ejusdem cavitatis delata sursum reflectitur, egrediturque angustias sterni, et claviculis medullis conscens, quibus ut fulcro nititur, ad thoracem se flexit.' —Miranda hercle modis omnibus constitutio et respiratio inservit et voci. Nam cum in stagnorum fundo edulia pro visu quaerat, longissimo indiguit collo, ne longa mora suffocationis incurreret periculum. Et certe dum dimidiam fere horam totum capite et collo pronis vado immergitur, pedibus in altum elatis coeloque obversis, ex ea arteriae quae pectoris dictae vaginas reclusa est portione, tanquam ex concho spiritum haurit. Blas. ib. c. 10.

(*d*) The structure of the tongue of the wood-pecker is very singular and remarkable, whether we look at its great length, its bones and muscles, its encompassing part of the neck and head, the better to exert itself in length; and again, to retract it into its cell; and lastly, whether we look at its sharp, horny, bearded point, and the glewy matter at the end of it, the better to stab, to stick unto, and draw out little maggots out of wood.

besides; but for a sample, I shall only insist upon the wonderful provision in the bill for the judging of the food, and that is by peculiar nerves lodged there-

‘*Utilis enim picis (saith Coiter) ad vermiculos, formicas, aliaque insecta venanda talis lingua foret. Siquidem picus, innata sua sagacitate cum deprehendit alibi in arboribus, vel carie, vel alia de causa cavatis, vermes insectaque delitescere, ad illas volitat, seseque digitis, ungulisque posterioribus robustissimis, et caudae pennis rigidissimis sustentat, donec valido ac peracuto rostro arborem pertundat: arbore pertusa, foramini rostrum immittit, ac quo animalcula stridore excitet percussatque, magnam in arboris cavo emittit vocem, insecta voriferatione hac concitata huc illucque repunt; picus vero linguam suam exerit, atque aculeis hamisque animalia insigit, infixata attrahit et devorat.*’ Vide Blasii, ubi supra, p. 2. c. 24.

(c) I have before, in book iv. chap. 3. note (t), p. 142. taken notice of what others have observed concerning the inner ear of birds, reserving my own observations for this place: which I hope may be acceptable, not only for being some of them new, but also shewing the mechanism of hearing in general.

In this organ of birds, I shall take notice only of three parts, the membranes and cartilages; the columella; and the conclave: the drum, as some call it, or *membrana tympani*, as others, consists of two membranes, the outer which cover the whole meatus, bason, or drum, as some call it, and the inner membrane. To support, distend, and relax the outermost, there is one single cartilage, reaching from the side of the meatus, to near the middle of the membrane. On the top of the columella is another cartilage, consisting of three branches, a, b, c, in Fig. 23. The longest middle branch a, is joined to the top of the single upper cartilage before spoken of, and assists it to bear up the upper outer membrane: the two branches, b, c, are joined to the os petrosus, at some distance from the outer membrane: upon this inner cartilage, is the inner membrane fixed, the two outer sides of which, a, b, and a, c, are joined to the outer membrane, and make a kind of a three square bag. The design of the two branches or legs of the cartilage, b, c, are, I conceive, to keep the cartilage and columella from wavering side-ways, and to hinder them from flying too much back: there is a very fine slender ligament extended from the opposite side, quite cross the meatus or bason, to the bottom of the cartilage, near its joining to the columella. Thus much for the *membranæ tympani*, and their cartilages.

The next part is the columella, as Schellhammer calls it. This is a very fine, thin, light, bony tube; the bottom of which spreads about, and gives it the resemblance of a wooden pot lid, such as I have seen in country-houses. It exactly shuts into, and covers the foramen of the conclave, to which it is braced all round, with

in for that purpose ; small and less numerous in such as have the assistance of another sense, the eye ; but large, more numerous, and thickly branched about,

a fine subtle membrane, composed of the tender auditory nerve. This bottom or base of the columella, I call the operculum.

The last part, which some call the labyrinth and cochlea, consisting of branches more like the canales semicirculares in man, than the cochlea, I call the conclave auditus. It is, as in most other animals, made of hard context bone. In most of the birds I have opened, there are circular canals, some larger some lesser, crossing one another at right angles, which open into the conclave. But in the goose it is otherwise, there being cochleous canals, but not like those of other birds. In the conclave, at the side opposite to the operculum, the tender part of the auditory nerve enters, and lineth all those inner retired parts, viz. the conclave and canals.

As to the passages, columnae, and other parts observable in the ear of birds, I shall pass them by, it being sufficient to my purpose, to have described the parts principally concerned in the act of hearing. And as the ear is in birds the most simple and incomplex of any animal's ear; so we may from it make an easy and rational judgement, how hearing is performed, viz. sound being a tremor or undulation in the air, caused by the collision of bodies, doth, as it moves along, strike upon the drum, or membrana tympani, of the ear : which motion, whether strong or languid, shrill or soft, tuneful or not, is at the same instant impressed upon the cartilages, columella, and operculum, and so communicated to the auditory nerve in the conclave.

And now if we compare the organ and act of hearing with those of sight, we shall find that the conclave is to hearing, as the retina is to sight; that sonorous bodies make their impressions thereby on the brain, as visible objects do by the retina. Also, that as there is an apparatus in the eye, by the opening and shutting of the pupil, to make it correspond to all the degrees of light, so there is in the ear, to make it conformable to all the degrees of sound, a noble train of little bones and muscles in man, etc. to strain and relax the membrane, and at the same time to open and shut the basis of the stapes (the same as what I call the operculum in birds) : but in birds there is a more simple, but sufficient apparatus for this purpose, tender cartilages, instead of bones and joints, to correspond to the various impressions of sounds, and to open and shut the operculum. Besides which, I suspect the ligament I mentioned, is only the tendon of a muscle, reaching to the inner membrana tympani, and joined thereto, as I find by a stricter scrutiny, and not to the cartilage, as I imagined. By this muscle, the inner membrane, and by means of that the outer also, can be distended or relaxed, as it is in man, by the malleus and its muscle, etc.

to the very end of the beak, in such as hunt for their food out of sight in the waters, in mud, or under ground (*f*).

And now from the head and mouth, pass we to its near ally, the stomach, another no less notable than useful part; whether we consider the elegance of its fibres and muscles, or its multiplicity; one to soften and macerate, another to digest; or its variety, suited to various foods, some membranous, agreeable to the frugivorous, or carnivorous kind; some musculous and strong (*g*), suited to the comminu-

(*f*) 'Flat-billed birds, that grope for their meat, have three pair of nerves, that come into their bills, whereby they have that accuracy to distinguish what is proper for food, and what to be rejected by their taste when they do not see it. This was most evident in a duck's bill and head; ducks having larger nerves that come into their bills than geese, or any other bird that I have seen; and therefore quaffer and grope out their meat the most. But then I discovered none of these nerves in round-billed birds. But since, in my anatomies in the country, in a rook, I first observed two nerves that came down betwixt the eyes into the upper bill, but considerably smaller than any of the three pair of nerves in the bills of ducks, but larger than the nerves in any other round-billed birds. And it is remarkable that these birds, more than any round billed birds, seem to grope for their meat in cow-dung,' etc. Mr J. Clayton, in *Philos. Transf.* No. 206.

'I observed three pair of nerves in all the broad billed birds, that I could meet with, and in all such as feel for their food out of sight, as snipes, woodcocks, curlews, geese, ducks, teals, widgeons, etc. These nerves are very large, equalling almost the optic nerve in thickness.—Two are distributed nigh the end of the upper bill, and are there very much expanded, passing through the bone into the membrane, lining the roof of the mouth.' Dr A. Moulen, *ibid.* No. 199. Or both in Mr Lowthorp's *Abridg.* vol. II. p. 861, 862.

(*g*) The gizzard is not only made very strong, especially in the granivorous; but hath also a faculty of grinding what is therein: for which purpose the bird swalloweth rough stones down, which when grown smooth, are rejected and cast out of the stomach as useless. This grinding may be heard in falcons, eagles, etc. by laying the ear close to them, when their stomachs are empty, as the famous Dr Harvey saith, *De Gener.* l. 7.

As to the strength of the gizzard, and the use of stones to the digestion of fowls, divers curious experiments may be met with,

tion, and grinding of corn and grain, and so to supply the defect of teeth.

And now to this specimen of the parts, I might add many other things, no less curiously contrived, made, and suited to the occasions of these volatiles; as particularly the structure and lodgement of the lungs (*h*); the configuration of the breast, and its bone, made like a keel, for commodious passage through the air, to bear the large and strong muscles, which move the wings, and to counterpoise the body, and support and rest it upon at roost. The neck also might deserve our notice, always either exactly proportioned to the length of the legs, or else longer, to hunt out food, to search in the waters (*i*); as also to counterpoise the body in flight (*k*). And lastly,

tried by signeur Redi, with glass bubbles, solid glass, diamonds, and other hard bodies. See his Exp. Nat.

(*h*) It is no less remarkable in birds, that their lungs adhere to the thorax, and have but little play, than that in other animals they are loose, and play much, which is a good provision for their steady flight. Also they want the diaphragm, and instead thereof have divers large bladders made of thin transparent membranes, with pretty large holes out of one into the other. These membranes seem to me to serve for ligaments, or braces to the viscera, as well as to contain air. Towards the upper part, each lobe of the lungs is perforated in two places, with large perforations; whereof one is towards the outer, the other towards the inner part of the lobe. Through these perforations, the air hath a passage into the belly, as in book i. chap. 1. note (*b*), p. 41. that is, into the forementioned bladders; so that by blowing into the aspera arteria, the lungs will be a little raised, and the whole belly blown up, so as to be very turgid. Which doubtless is a means to make their bodies more or less buoyant, according as they take in more or less air, to facilitate thereby their ascents and descents; like as it is in the air-bladders of fishes, in the last cited place, note (*i*), p. 41.

(*i*) 'Such birds as have long legs, have also a long neck; for that otherwise they could not commodiously gather up their food, either on land, or in the water. But on the other side, those which have long necks, have not always long legs, as in swans——whose necks serve them to reach to the bottom of rivers,' etc. Willoughby's Ornithol. l. 1. c. 1. sect. 7.

(*k*) We have sufficient instances of this in geese, ducks, etc. whose wings (their bodies being made for the convenience of swimming) are placed out of the centre of gravity, nearer the

I might here take notice of the defect of the diaphragm, so necessary in other animals to respiration; and also of divers other parts redundant, defective, or varying from other animals. But it would be tedious to insist upon all; and therefore to the examples already given, I would rather recommend a nice inspection (1) of those curious works of God, which would be manifest demonstrations of the admirable contrivance and oeconomy of the bodies of those creatures.

From the fabric therefore of their bodies, I shall pass to a glance of one or two things, relating to their state; and so conclude this genus of the animal world.

CH A P. III.

Of the MIGRATION of BIRDS.

CONCERNING the state of this tribe of animals, the first thing I shall speak of, by reason God himself instanceth in it, shall be their migration, mentioned Jer. viii. 7. 'Yea, the stork in the heaven knoweth her appointed times, and the turtle,

head. But the extending the neck and head in flight, causeth a due equipoise and libration of the body upon the wings; which is another excellent use of the long necks of these birds, besides that of reaching and searching in the waters for their food.

But in the heron, whose head and long neck, although tucked up in flight, over-balance the hinder part of the body; the long legs are extended in flight, to counterpoise the body, as well as to supply what is wanting in the tail, from the shortness of it.

(1) Steno thus concludes his myology of the eagle, 'Imperfecta haec musculorum descriptio, non minus arida est legentibus, quam inspectantibus fuerit jucunda eorundem praeparatio. Elegantissima enim mechanices artificia, creberrime in illis obvia, verbis non nisi obscure exprimuntur, carniarum autem ductu, tendinum colore, insertionum proportionem, et trochlearum distributionem oculis exposita omnem superant admirationem.' Steno in Blas. Anat. Animal. p. 2. c. 4.

‘ and the crane, and the swallow observe the time of
‘ their coming; but my people,’ etc.

In which act of migration, there are two things to me exceedingly notable. One is what the text speaks of, their knowing their proper times for their passage, when to come (*a*), when to go; as also that some should come, when others go; and some others go, when these come. There is no doubt but the temperature of the air, as to heat and cold, and their natural propensity to breed their young, may be great incentives to those creatures to change their habitation: but yet it is a very odd instinct, that they should at all shift their habitation; that some certain place is not to be found in all the terraqueous globe, affording them convenient food and habitation all the year, either in the colder climes, for such as delight in the colder regions; or the hotter, for such birds of passage as fly to us in summer.

Also it is somewhat strange, that those untaught, unthinking creatures should so exactly know the best and only proper seasons to go and come. This gives us good reason to interpret the **מֵעֵרָו** *appointed times* (*b*) in the text, to be such times as the Creator hath appointed those animals, and hath accordingly, for this end, imprinted upon their natures such an instinct, as exciteth and moveth them thus, at proper times, to fly from a place that would obstruct their generation, or not afford convenient food for them, and their young, and betake themselves to another

(*a*) ‘ Curiosa res est, scire, quam exacte hoc genus avium
‘ [gruum] quotannis observet tempora sui reditus ad nos. Anno
‘ 1667. primæ grues comparuerunt in campestribus Pisæ 20 Feb.
etc. F. Redi Exp. Nat. p. 100. ubi plura.

(*b*) From **עָרָו** ‘ indixit, constituit, scil. locum, vel tempus,
‘ ubi vel quando aliquid fieri debet.’ Buxt. in verb.

‘ De voluntate sua certiores reddidit.’ C. Kircher Concor-
dant. Pars 1. Col. 1846. **מֵעֵרָו** ‘ Generaliter pro re aliqua cer-
‘ ta, attestata, et definita accipitur. 1. Pro tempore certo et con-
‘ stituto. 2. Deinde pro festo seu sollemnitate, quæ certo et sta-
‘ to tempore celebratur. 3. Pro loco certo constituto.’ Id. ibid.
Col. 1847.

place, affording all that is wanting for food or incubation.

And this leads me to another thing remarkable in this act of migration; and that is, that those unthinking creatures should know what way to steer their course (*c*), and whither to go. What but the great Creator's instinct should ever move a poor foolish bird, to venture over vast tracks of land, but especially over large seas? If it should be said, that by their high ascent up into the air, they can see cross the seas; yet what should teach or persuade them, that that land is more proper for their purpose than this? That Britian, for instance, should afford them better accommodations than Egypt (*d*), than the Cana-

(*c*) 'Quis non cum admiratione videat ordinem et politiam peregrinantium avium, in itinere, turmatim volantium, per longos terrarum et maris tractus absque acu marina—Quis eas certum iter in aeris mutabili regione docuit? Quis praeteritae signa, et futurae viae indicia? Quis eas ducit, nutrit, et vitae necessaria ministrat? Quis insulas et hospitia illa, in quibus victum reperiatur, indicavit; modumque ejusmodi loca in peregrinationibus suis inveniendi? Haec sane superant hominum captum et industriam, qui non nisi longis experienciis, multis itinerariis, chartis geographicis, —et acus magneticae beneficio, —ejusmodi marium et terrarum tractus conficere tentant, et audent.' Lud. de Beaufort. Cosm. Divina, sect. 5. c. 1.

(*d*) I instance particularly in Egypt, because Mr Willoughby thinks swallows fly thither, and into Ethiopia, etc. and that they do not lurk in holes, or under water, as Olaus Magnus reports. Vide Ornith. l. 2. c. 3. But Etmuller puts the matter out of doubt, who saith, 'Memini me plures, quam quas medimnus cepit, hirundines arcte coacervatas inter piscinae cannas, sub glacie prorsus ad sensum exanimes, pulsantes tamen, reperiisse.' Etmul. Dissert. 2. c. 10. sect. 5. This, as it is like what Olaus Magnus saith, so is a confirmation of it. The archbishop's account is, 'In septentrionalibus aquis saepius casu piscatoris extrahuntur hirundines, in modum conglomeratae massae, quae ore ad os, et ala ad alam, et pede ad pedem post principium autumni sese inter cannas descensurae colligunt.—Massa autem illa per imperitos adolescentes—extracta, atque in aestuaria portata, caloris accessu hirundines resolutae, volare quidem incipiunt, sed exiguo tempore durant.' Ol. Mag. Hist. l. 19. c. 20.

Since my penning this note, we had, at a meeting of the Royal Society, Feb. 12. 1712-13, a farther confirmation of swallows

ries, than Spain, or any of those many intermediate places over which some of them probably fly.

And lastly, to all this, let us briefly add the accommodations these birds of passage have to enable them to take such long flights, viz. the length of their wings, or their more than ordinary strength for flight (e).

CHAP. IV.

Of the INCUBATION of BIRDS.

ANother thing relating to the state of this tribe of animals, is their incubation.

And first, the egg itself deserves our notice. Its parts within, and its crusty coat without, are admi-

retiring under water in winter, from Dr Colas, a person very curious in these matters; who speaking of their way of fishing in the northern parts, by breaking holes, and drawing their nets under the ice, saith, that he saw sixteen swallows so drawn out of the lake of Samrodt, and about thirty out of the king's great pond in Rosneilen; and that at Schlebittin, near an house of the earl of Dohna, he saw two swallows just come out of the waters, that could scarce stand, being very wet and weak, with their wings hanging on the ground; and that he hath observed the swallows to be often weak for some days after their appearance.

(e) As swallows are well accommodated for long flights, by their long wings, so are quails by the strength of their pectoral muscles, by the breadth of their wings, etc. For quails have but short wings for the weight of their body; and yet they fly from us into warmer parts against winter, and to us in the spring, crossing our seas. So divers travellers tell us, they cross the Mediterranean twice a year, flying from Europe to Africa, and back again: thus Bellonius, in Mr Willoughby, saith, 'When he sailed from Rhodis to Alexandria of Egypt, many quails, flying from the north towards the south, were taken in our ship; whence I am verily persuaded, that they shift places: for formerly also, when I sailed out of the isle of Zant to Morea, or Negropont, in the spring time, I had observed quails flying the contrary way, from south to north, that they might abide there all summer. At which time also, there were a great many taken in our ship.' Ornith. p. 170.

rably well fitted for the business of incubation. That there should be one part provided for the formation of the body (*a*), before its exit into the world, and another for its nourishment, after it is come into the world, till the bird is able to shift for and help itself; and that these parts should be so accurately braced, and kept in due place (*b*), is certainly a designed, as well as curious piece of workmanship.

(*a*) 'The chicken is formed out of, and nourished by the white alone, till it be grown great. The yolk serves for the chicken's nourishment, after it is well grown, and partly also after it is hatched. For a good part of the yolk remains after exclusion, being received into the chicken's belly; and being there reserved, as in a store-house, is by the [appendicula, or ductus intestinalis], as by a funnel, conveyed into the guts, and serves instead of milk,' etc. Willoughby's Ornith. l. 1. c. 3. 'Ipsum animal ex albo liquore ovi corporatur. Cibus ejus in luteo est.' Plin. l. 10. c. 53.

Aristotle saith, 'The long sharp eggs bring females; the round ones, with a larger compass at the sharper end, males.' Hist. An. l. 6. c. 2. After which he tells of a sort at Syracuse, that sat drinking so long, till eggs were hatched; as also of the custom of Egypt, of hatching eggs in dunghills.

(*b*) As the shell and skin keep the yolk and two whites together; so each of the parts (the yolk and inner white at least), are separated by membranes, involving them. At each end of the egg is a treddle, so called, because it was formerly thought to be the sperm of the cock. 'But the use of these,' (saith Dr. Harvey, in Willoughby's Ornith. c. 3) is to be as it were, the poles of this microcosm, and the connections of all the membranes twisted and knit together, by which the liquors are not only conserved, each in its place, but do also retain their due position one to another.' This, although in a great measure true, yet doth not come up to what I have myself observed; for I find, that these chalazae, or treddles, serve not barely to keep the liquors in their place, and position to one another; but also to keep one and the same part of the yolk uppermost, let the egg be turned nearly which way it will; which is done by this mechanism: the chalazae are specifically lighter than the whites, in which they swim; and being braced to the membrane of the yolk, not exactly in the axis of the yolk, but somewhat out of it, causeth one side of the yolk to be heavier than the other; so that the yolk, being by the chalazae made buoyant, and kept swimming in the midst of two whites, is by its own heavy side kept with the same side always uppermost; which uppermost side, I have some reason to think, is that on which the cicatricula lies; that being

And then as to the act itself of incubation, what a prodigious instinct is it in all or almost all the several species of birds, that they, and only they, of all creatures, should betake themselves to this very way of generation! How should they be aware that their eggs contain their young, and that their production is in their power (c)! What should move them to betake themselves to their nests, and there with delight and patience to abide the due number of days! And when their young are gotten into the world, I have already shewn how admirable their art, their care, and *Στοργή* is in bringing them up until, and only until, they are able to shift for themselves.

And lastly, when almost the whole tribe of birds do thus, by incubation, produce their young, it is a wonderful deviation, that some few families only should do it in a more novercal way (d), without any care or trouble at all, only by laying their eggs in the sand, exposed to the heat and incubation of the sun. Of this the holy scripture itself gives us an instance

commonly uppermost in the shell, especially in some species of eggs more, I think, than others.

(c) All birds lay a certain number of eggs, or nearly that number, and then betake themselves to their incubation; but if their eggs be withdrawn, they will lay more. Of which, see Mr Ray's Wisdom of God, p. 137.

(d) The *tahon* is a bird no bigger than a chicken, but is said to lay an egg larger than a goose's egg, and bigger than the bird itself. These they lay a yard deep in the sand, where they are hatched by the warmth of the sun; after which they creep out, and get to sea for provisions, Navarette's Account of China, in Collect. of voyages, vol. 1. This account is, in all probability, borrowed from Nieremberg, or Hernandez, (that copied from him), who calls this bird by the name of *Daic*, and its eggs *tahon*, not the bird itself, as Navarette doth. But my friend, Mr Ray, saith of it, '*Historia isthaec proculdubio fabulosa et fallax est. Quamvis enim aves nonnullae maxima ova pariunt, ut v. g. Alcae, Lomwiae, Anates, Arcticae, etc. hujusmodi tamen nonnumquam duntaxat, non plura, ova ponunt antequam incubent: nec ullum in rerum natura avem dari existimo cujus ova albumina careant. Cum albumen praecipua ovi pars sit, quodque propter muni- mentum foetui alimentum subministrat.*' Raii Synop. Av. Metaph. p. 155.

in the ostrich : of which we have an hint, Lam. iv. 3. ' The daughter of my people is become cruel like ' the ostriches in the wilderness.' This is more plainly expressed in Job xxxix. 14. 15. 16. 17. ' [The ' ostrich] leaveth her eggs in the earth, and warmeth ' them in the dust, and forgetteth that the foot may ' crush them, or that the wild beast may break them. ' She is hardened against her young ones as though ' they were not hers : her labour is in vain without ' fear. Because God hath deprived her of wisdom, ' neither hath he imparted unto her understanding.' In which words I shall take notice of three things : 1. Of this anomalous way of generation. It is not very strange, that no other incubation but that of the sun, should produce their young ; but it is very odd and wonderful that any one species should vary all from the rest of the tribe. But above all, 2. The singular care of the Creator, in this case, is very remarkable, in supplying some other way the want of the parent-animal's care and *ἐπιτροπή* (e), so that the young should, notwithstanding, be bred up in those large and barren deserts of Arabia and Africa, and such like places where those birds dwell, the most unlikely and unfitting, in all human opinion, to afford sustenance to young helpless creatures ; but the fittest therefore, to give demonstrations of the wisdom, care, and especial providence of the infinite Creator and Conservator of the world. 3. The last thing I shall remark is, that the instincts of irrational animals, at least of this specified in the text, are attributed to

(e) ' The eggs of the ostrich being buried in the sand, are cherished only by the heat of the sun, till the young be excluded : for the writers of natural history do generally agree, that the old birds, after they have laid and covered their eggs ' in the sand, forsake them, and take no more care of them.' Willough. Ornith. l. 2. c. 8. sect. 1.

But there is another ostrich [of America] which Acaret tells us of, that takes more care of her young, by carrying four of her eggs, a little before she hatcheth, to four parts of her nest, there to breed worms for food for her young. Acaret's Disc. in Phil. Transf. No. 89.

God. For the reason the text gives why the ' ostrich ' is hardened against her young ones, as though they ' were not hers,' is, ' because God hath deprived her ' of wisdom, and not imparted understanding to her ;' i. e. he hath denied her that wisdom, he hath not imparted that understanding, that *Σοφία*, that natural instinct to provide for and nurse up her young, that most other creatures of the same, and other tribes, are endowed with.

Thus I have dispatched what I intended to insist upon concerning the state of this set of animals ; of which, as also of their admirable instincts, a great deal more might deserve our especial observation ; particularly the admirable curiosity, art, and variety of nidification (*f*), used among the various species of birds ; the great sagacity, and many artifices used by them in the investigation and capture of their prey (*g*), the due proportion of the more and less useful, the scarcity of the voracious and pernicious, and the plenty of the mansuete and useful (*h*). Also the variety of their motion and flight might deserve consideration, the swiftness of such whose food is to be sought in far distant places, and different seasons (*i*) ; the slower motion, and short flights, of others more domestic ; and even the awkwardness of some others to flight, whose food is near at hand, and to be gotten without any great occasion of flight (*k*). These, and divers other such like things as these, I say, I might have spoken more largely unto ; but I shall pass them by with only a bare mention, having already

(*f*) See book iv. chap. 1

(*g*) See book iv. chap. 11. and 14.

(*h*) See book iv. the beginning of chap. 10.

(*i*) See book iv. chap. 8.

(*k*) The colymbi, or douckers, having their food near at hand in the waters, are remarkably made for diving therein. Their heads are small, bills sharp-pointed, wings small, legs flat and broad, and placed backward, and nearer the tail than in other birds ; and lastly, their feet, some are whole-footed, some cloven-footed, but withal fin-toed. Vide Willough. Ornith. l. 3. sect. 5.

taken notice of them in the company of other matters of the like nature, and manifested them to be acts of excellent design, wisdom, and providence, in the great Creator.

CHAP. V.

The Conclusion.

AND now if we reflect upon the whole matter, we shall here find another large tribe of the creation, abundantly setting forth the wisdom and glory of their great Creator. We praise the ingenuity and invention of men, for the contrivance of various pneumatic engines; we think them witty, even for their unsuccessful attempts to swim in, and sail through that subtle element the air; and the curious mechanism of that artist is had in remembrance, and praised to this day, who made a dove, or an eagle (*a*) to fly but a short space. And is not therefore all imaginable honour and praise due to that infinite Artist, that hath so admirably contrived and made all the noble variety of birds; that hath, with such incomparable curiosity and art, formed their bodies from head to tail, without and within, that not so much as any muscle, or bone, no, not even a feather (*b*) is unartificially made, misplaced, redundant, or defective, in all the several families of this large tribe? But every thing is so incomparably performed, so nicely fitted up for flight, as to surpass even the imitation of the most ingenious artificer among mortal rational beings.

(*a*) Vide book v. chap. i. note (*γ*), p. 274.

(*b*) 'Deus non solum angelum, et hominem, sed nec exiguum et contemptibilis animantis viscera, nec avis pennulam, nec herbae flosculum, nec arboris folium, sine suarum partium convenientia dereliquit.' Augustin. de Civ. Dei. l. 5. c. 11.

BOOK VIII.

Of INSECTS and REPTILES.

CHAP. I.

Of INSECTS in General.

HAVING dispatched that part of the animal world, which used to be accounted the more perfect, those animals stiled less perfect, or imperfect, will next deserve a place in our survey, because when strictly inquired into, we shall find them to be so far from deserving to be accounted mean and despicable parts of the creation, owing their original and production to putrefactions, etc. as some have thought, that we shall find them, I say, noble, and most admirable works of God. For as the famous natural historian, Pliny (*a*), prefaceth his Treatise of Insects, to prevent the reproach of condescending; as might be thought, to so mean a subject; 'In great bodies, saith he, nature had a large
' and easy shop to work upon obsequious matter;
' whereas, in these so small, and as it were no
' bodies, what footsteps of reason, what power, what
' great perfection is there!' Of this having given an instance or two of the exquisite senses, and curious make of some insects (*b*), he then goes on, 'We admire, saith he, the turrigerous shoulders of elephants,

(*a*) 'In magnis siquidem corporibus,' etc. Plin. Nat. Hist. l. 11. c. 2.

(*b*) 'Ubi tot sensus collocavit in culice? Et sunt alia dictu miranda. Sed ubi visum in eo praetendit; Ubi gustatum applicavit? Ubi odoratum inseruit? Ubi vero truculentam illam et portione maximam vocem ingeneravit? Qua subtilitate perinas adnexuit? praelongavit pedum crura? Disposuit jejuna cavcam, uti alvum? Avidam sanguinis, et potissimum humani sitim, accendit? Telum vero perfodiendo tergori, quo spiculari ingenio? Atque ut in c. paci, cum cerni non possit exilitas, ita

the lofty necks and crests of others; but, saith he, the nature of things is never more complete than in the least things.' For which reason he intreats his readers, as I do mine, 'that because they slighted many of the things themselves which he took notice of, they would not therefore disdainfully condemn his accounts of them, since, saith he, in the contemplation of nature, nothing ought to seem superfluous.'

Thus that eminent naturalist hath made his own, and my excuse too; the force and verity whereof will farther appear, by what I shall say of these animals, which (as despicable as they have been, or perhaps may be thought) we shall find as exquisitely contrived, and curiously made for that place and station they bear in the world, as any other part of the animal world. For if we consider the innumerable variety of their species, the prodigious numbers of individuals, the shape and make of their little bodies, and every part thereof, their motion, their instincts, their regular generation and production; and, to name no more, the incomparable beauty and lustre of the colours of many of them, what more admirable and more manifest demonstration of the infinite Creator, than even this little condemned branch of the animal world! But let us take a short view of particulars.

CHAP. II.

Of the SHAPE and STRUCTURE of INSECTS.

LET us begin with the shape and fabric of their bodies: which, although it be somewhat dif-

'reciproca geminavit arte, ut fodiendo acuminatum pariter for-
'bendoque fistulosum esset. Quos teredini ad perforanda robora
'cum sono teste dentes affixit? Potissimumque e ligno cibatum
'fecit: sed turrigeros elephantorum miramur humeros, tauro-
'rumque colla, et truces in sublime jactus, tigrum rapinas, leo-
'num jubas, cum rerum natura nusquam magis quam in minimis,
'tota sit.' Plin. *ibid.*

ferent from that of birds, being particularly, for the most part, not so sharp before, to cut and make way through the air, yet is better adapted to their manner of life. For, considering that there is little necessity of long flights, and that the strength and activity of their wings doth much surpass the resistance their bodies meet with from the air, there was no great occasion their bodies should be so sharpened before. But the condition of their food, and the manner of gathering it, together with the great necessity of accurate vision, by that admirable provision made for them by the reticulated cornea of their eyes; these things, I say, as they required a larger room, so were a good occasion for the largeness of the head, and its amplitude before. But for the rest of their body, all is well made, and nicely poised for their flight, and every other of their occasions.

And as their shape, so the fabric and make of their bodies is no less accurate, admirable, and singular; nor built throughout with bones, and covered with flesh and skin, as in most other animals; but covered with a curious mail of a middle nature (a), serving both as skin and bone too, for the shape, as well as strength and guard, of the body; and as it were on purpose to shew, that the great Contriver of nature is not bound up to one way only.

CH A P. III.

Of the EYES and ANTENNAE of INSECTS.

TO this last-mentioned guard, we may add that farther guard provided in the eyes and anten-

(a) 'Insecta non videntur nervos habere, nec ossa, nec spinas, nec cartilaginem, nec pinguia, nec carnes, nec cruram quidem fragilem, ut quaedam marina, nec quae jure dicatur cutis: sed mediae cujusdam inter omnia haec naturae corpus,' etc. Plin. Nat. Hist. l. 11. c. 4.

nae. The structure of the eye is, in all creatures, an admirable piece of mechanism; but that observable in the eyes of insects so peculiar, that it must needs excite our admiration: fenced with its own hardness, yea, even its own accurate vision, is a good guard against external injuries; and its cornea, or outward coat, all over beset with curious, transparent, lenticular inlets (*a*), enabling those creatures to see, no doubt, very accurately every way, without any interval of time or trouble to move the eye towards objects.

And as for the other part, the antennae, or feelers, whatever their use may be in cleaning the eyes, or other such like use; they are, in all probability, a good guard to the eyes and head, in their walk and flight, enabling them, by the sense of feeling, to discover such annoyances, which, by their proximity, may perhaps escape the reach of the eyes and sight (*b*).

(*a*) The cornea of flies, wasps, etc. are so common an entertainment with the microscope, that every body knows it is a curious piece of lattice-work. In which this is remarkable, that every foramen is of a lenticular nature; so that we see objects through them topsy-turvy, as through so many convex glasses; yea, they become a small telescope, when there is a due focal distance between them and the lens of the microscope.

This lenticular power of the cornea, supplies, as I imagine, the place of the chryalline, if not of the vitreous humour too, there being neither of those humours that I could ever find, (although, for truth's sake, I confess I have not been so diligent as might in this inquiry); but instead of humours and tunics, I imagine that every lens of the cornea hath a distinct branch of the optic nerve ministering to it, and rendering it as so many distinct eyes. So that as most animals are binocular, spiders for the most part otonocular, and some, (as Mr Willoughby thought, *tail Hist. Insect. p. 12.*) senocular; so flies, etc. are multocular, having as many eyes as there are perforations in their cornea. By which means, as other creatures are obliged to turn their eyes to objects, these have some or other of their eyes ready placed towards objects, nearly all round them: thus particularly it is in the dragon-fly, libella, the greatest part of whose head is possessed by its eyes: which is of excellent use to that predacious insect, for the ready seeing and darting at small flies all round it in which it preys.

(*b*) It is manifest, that insects clean their eyes with their fore-

Besides which, they are a curious piece of workmanship, and in many a very beautiful piece of (c) garniture to the body.

CH A P. IV.

Of the PARTS and MOTION of INSECTS.

FROM the head pass we to the members, concerned in their motion. And here we have a copious subject, if I was minded to expatiate. I might take notice of the admirable mechanism in those that creep; the curious oars in those amphibious insects that swim and walk (a); the incompa-

legs, as well as antennae. And considering, that as they walk along, they are perpetually feeling, and searching before them, with their feelers, or antennae; therefore I am apt to think, that besides wiping and cleaning the eyes, the uses here named may be admitted. For as their eyes are immovable, so that no time is required for the turning their eyes to objects; so there is no necessity of the retina, or optic nerve being brought nigher unto, or set farther off from the cornea, which would require time, as it is in other animals: but their cornea and optic nerve, being always at one and the same distance, are fitted only to see distant objects, but not such as are very nigh: which inconvenience the feelers obviate, lest it should be prejudicial, in occasioning the insect to run its head against any thing.

And that this, rather than the wiping the eyes, is the chief use of the feelers, is farther manifest from the antennae of the flesh-fly, and many other insects, which are short, and strait, and incapable of being bent unto, or extended over the eyes: as also from others enormously long, such as those of the capricorni, or goat-chafers, the cadew-fly, and divers others, both beetles and flies.

(c) The lamellated antennae of some, the clavellated of others, the neatly articulated of others, the feathered and divers other forms of others, of the scarab, papilionaceous gnat, and other kinds, are surprisingly beautiful, when viewed through a microscope. And in some those antennae distinguish the sexes: as in the gnat-kind, all those with tufts, feathers, and brush-horns, are males; those with single-shafted antennae, are females.

(a) All the families of hydrocanthari, notonecti, etc. have their hindmost legs made very nicely, with commodious joints flat, and bristles on each side towards the end, serving for oars.

able provision made in the feet of such as walk, or hang upon smooth surfaces (*b*) ; the great strength and spring in the legs of such as leap (*c*) ; the strong and well made feet and talons of such as dig (*d*) : and, to name no more, the admirable faculty of such as cannot fly, to convey themselves with speed and safety, by the help of their webs (*e*), or some other

swim ; and then, nearer the body, are two stiff spikes, to enable them to walk, when occasion is.

(*b*) I might here name divers flies, and other insects, who, besides their sharp hooked nails, have also skinny palms to their feet, to enable them to stick on glass. and other smooth bodies, by means of the pressure of the atmosphere. But because the example will illustrate another work of nature, as well as this, I shall chuse a singular piece of mechanism, in one of the largest sorts of hydrocanthari. Of these large ones there are two sorts, one largest, all black, with antennae handsomely embossed at the ends. The other somewhat lesser, hardly so black, with capillary antennae ; the forehead, edges of the vaginae, and two rings on the thorax, of a tawny colour. The female hath vaginae prettily furrowed, the male smooth. But that which is most to our purpose in this male, is a flap, or hollowish cap near the middle joint of the fore-legs, which, when clapped on the shoulders of the female in coitu, sticks firmly thereon : after the manner as I have seen boys carry heavy stones, with only a wet piece of leather clapped on the top of the stone.

(*c*) Thus grasshoppers and crickets have brawny strong thighs, with long, slender, but strong legs, which enable them to leap with great agility and strength.

(*d*) I have wondered to see with what great quickness, art, and strength, many vespaee-ichneumons, wild-bees, and beetles, perforate the earth, yea, even wood itself : but the most remarkable animal in this way, is the mole-cricket, in book iv. chap. 23. note (*f*), p. 237.

(*e*) I have, with pleasure, often seen spiders dart out their webs, and sail away by the help thereof. For the manner of which, see Mr Lowthorp's Abridgm. vol. 2. p. 794. from Dr Lister and Dr Hulse, who both claimed the discovery thereof. And both do seem to have hit thereupon, without any foreknowledge of what each other hath discovered, as is said in the last cited place, and as I more particularly find by Mr Ray's Philoso. Letters, printed Anno 1718, p. 95, etc. By which also I find, the two ingenious doctors were very modest in their claims, and very amicable in the matter. In one of Dr Lister's to Mr Ray, he thinks there is a fair hint of the darting of spiders in Aristot. Hist. An. l. 9. c. 39. And in Pliny, l. 11. c. 24. But for their sailing, that the ancients are silent of, and he thinks it was first seen by him. And in another letter, Jan. 20. 1670. speaking of the

artifice, to make their bodies lighter than the air (*f*): these, and a multitude of other such things as these, I might, I say, take notice of, as great evidences of the infinite Creator's wisdom: but lest I should be too tedious, I will confine my observations to the legs and wings only. And these, at first view, we find to be incomparably fitted up for their intended service, not to overload the body, nor in the least to retard it; but to give it the most proper and convenient motion. What, for example, can be better contri-

height spiders are able to fly, he saith, 'The last October, etc. I took notice that the air was very full of webs. I forthwith mounted to the top of the highest steeple on the Minster, [in York], and could thence discern them yet exceeding high above me. Some that fell, and were entangled upon the pinnacles, I took, and found them to be lupi; which kind seldom or never enter houses, and cannot be supposed to have taken their flight from the steeple.'

(*f*) There are, I imagine, divers animals, as well as spiders, that have some way of conveyance, as little known to us, as that of spiders formerly was. Thus the squillulæ, pulices arborecentes, and microscopical animalcules of the stagnating waters, so numerous in them, as to discolour sometimes the waters, and make them look as if they were tinged red, yellow, or green, or covered with a thick green scum; all which is nothing but animalcules of that colour. That these creatures have some way of conveyance, I conclude, because most stagnating waters are stocked with them, new pits and ponds, yea, holes and gutters on the tops of houses and steeples. That they are not bred there by equivocal generation, every ingenious, considering philosopher will grant; that they have not legs for travelling so far, is manifest from inspection: and therefore I am apt to think, that they have some faculty of inflating their bodies, or darting out webs, and making their bodies buoyant, and lighter than air; or their bodies, when dry, may be lighter than air, and so they can swim from place to place; or the eggs of such as are oviparous may be light enough to float in the air. But then the viviparous (as my late ingenious friend, Mr Charles King, shewed me the pulices aquaticæ arborecentes are; these, I say), cannot be thus way accounted for. The cause of these latter suspicions was that in the summer months, I have seen the pulices arborecentes and the green scum on the waters, nothing but animalcules, as I said, lie in a manner dry on the surface of the waters; at which time, as I have shewn in book iv. chap. 11. note (*n*), p. 196. those animalcules copulate; and, perhaps, they may, at the same time, change their quarters, and seek out new habitations for their numerous offspring, as well as themselves,

ved, and made for this service, than the wings ! Distended and strengthened by the finest bones, and these covered with the finest and lightest membranes, some of them adorned with the neat and beautiful feathers (*g*) ; and many of them provided with the finest articulations, and foldings, for the wings to be withdrawn, and neatly laid up in their vaginæ, and cases, and again readily extended for flight (*h*).

And then for the poising of the body, and keeping it upright, and steady in flight, it is an admirable artifice and provision for this purpose ; in some, by four wings (*i*) ; and in such as have but two, by pointels, and poises placed under the wings, on each side of the body.

(*g*) It is well known to all persons any way conversant in microscopical observations, that these elegant colours of moths, and butterflies, are owing to neat and well-made feathers, set with great curiosity and exactness in rows, and good order.

(*h*) All that have elytra, scarabs, (who have whole elytra, or reaching to the podex, or the *Ἡμιμυαλόπτεροι*, such as ear-wigs, and staphilini of all sorts), do, by a very curious mechanism, extend and withdraw their membranaceous wings, wherewith they chiefly fly ; and it is very pretty to see them prepare themselves for flight, by thrusting out, and unfolding their wings, and again withdraw those joints, and neatly fold in the membranes, to be laid up safely in their elytra or cases. For which service the bones are well placed, and the joints ministering thereunto are accurately contrived, for the most compendious, and commodious folding up the wings.

(*i*) For the keeping the body steady and upright in flight, it generally holds true, if I mistake not, that all the bipennated insects have poises joined to the body, under the hinder part of their wings : but such as have four wings, or wings with elytra, none. If one of the poises, or one of the lesser auxiliary wings be cut off, the insect will fly as if one side over-balanced the other, until it falleth on the ground ; so if both be cut off they will fly awkwardly, and unsteadily, manifesting the defect of some very necessary part. These poises, or pointels, are, for the most part, little balls set at the top of a slender stalk, which they can move every way at pleasure. In some they stand alone, in others, as in the whole flesh-fly tribe, they have little covers, or shields, under which they lie and move. The use, no doubt, of these poises, and secondary lesser wings, is to poise the body, and to obviate all the vacillations thereof in flight ; serving to the insect, as the long pole, laden at the ends with lead, doth the rope-dancer.

And lastly, it is an amazing thing to reflect upon the surprising minuteness, art, and curiosity of the joints (*k*), the muscles, the tendons, the nerves, necessary to perform all the motions of the legs, the wings, and every other part. I have already mentioned this in the larger animals; but to consider, that all those things concur in minute animals, even in the smallest mite; yea, the animalcules, that, without good microscopes, escape our sight; to consider, I say, that those minute animals have all the joints, bones, muscles, tendons, and nerves, necessary to that brisk and swift motion that many of them have, is so stupendous a piece of curious art (*l*), as plainly manifesteth the power and wisdom of the infinite Contriver of those inimitable fineries. But having named those minute animals, why should I mention

(*k*) As all the parts of animals are moved by the help of these; so there is no doubt but the minute animals have such like parts: but the muscles and tendons of some of the larger insects, and some of the lesser too, may be seen with a microscope.

(*l*) The minute curiosities, and inimitable fineries, observable in those lesser animals, in which our best microscopes discover no botch, no rude ill-made work, contrary to what is in all artificial works of man, do they not far more deserve our admiration, than those celebrated pieces of human art? Such as the cup made of a pepper-corn, by Oswald Nerlinger, that held 1200 ivory cups, all gilt on the edges, and having each of them a foot, and yet affording room for 400 more, in the *Ephem. Germ. T. 1. Addend. ad obs. 13.* Such also was Phaeton in a ring, which Galen thus reflects upon, when he speaks of the art and wisdom of the maker of animals, particularly such as are small: ‘Quanto,’ saith he, ‘ipsum minus fuerit, tanto majorem admirationem tibi excitabit; quod declarant opifices cum in corporibus parvis alii quid insculpant: cujus generis est quod nuper quidem in annulo Phaetonta quatuor equis invecum sculpsit. Omnes enim equi frenum, os, et dentes anteriores habebant,’ etc. And then having taken notice, that the legs were no bigger than those of a gnat, he shews that their make did not come up to those of the gnat; as also, saith he, ‘Major adhuc alia quaedam esse videtur artis ejus, qui pulicem condidit, vis atque sapientia, quod,’ etc. Cum igitur ars tanta in tam abjectis animalibus appareat, ‘quantam ejus vim ac sapientiam in praestantioribus inesse putabimus?’ (Galen. de usu Part. l. 17. c. 1. fin.)

only any one part of their bodies, when we have, in that little compass, a whole and complete body, as exquisitely formed; and, as far as our scrutiny can possibly reach, as neatly adorned, as the largest animal! Let us consider, that there we have eyes, a brain, a mouth, a stomach, entrails, and every other part of an animal body, as well as legs and feet; and that all those parts have each of them their necessary apparatus of nerves, of various muscles, and every other part that other insects have; and that all is covered and guarded with a well made tegument, beset with bristles, adorned with neat imbrications, and many other fineries. And lastly, let us consider in how little compass all art and curiosity may lie, even in a body many times less than a small grain of sand (*m*); so that the least drop of water can contain many of them, and afford them also sufficient room to dance and frisk about in (*n*).

Having surveyed as many of the parts of insects as I care to take notice only of; I shall, in the next place, say somewhat of their state, and circumstances of life. And here I shall take notice only of two things, which have been only hinted at before; but will deserve more particular consideration here, as being acts of a wonderful instinct; namely, their security of themselves against winter; and their special care of preserving their species.

(*m*) It will in some measure appear, how wonderfully some minute microscopical animalcules are, by what follows in the next note. But because more particular examples would be endless, I shall refer to the observations of Mr Lewenhoeck, and others, in the *Philos. Trans.* and elsewhere.

(*n*) It is almost impossible, by reason of their perpetual motion, and changing places, to count the number of the animalcules, in only a drop of the green scum upon water; but I guess I have sometimes seen not fewer than a 100 frisking about in a drop no bigger than a pin's head. But in such a drop of pepper-water, a far greater number; these being much less than those.

C H A P. V.

The SAGACITY of INSECTS to secure themselves against Winter.

IT is an extraordinary act of instinct and sagacity, observable in the generality of the insect-tribe, that they all take care to secure themselves, and provide against the necessities of winter: that when the distresses of cold and wet force them, they should retire to warm and dry places of safety, is not strange; but it is a prodigious act of the infinite Conservator's care, to enable some to live in a different kind of insect state; others to live, as without action, so without food; and others that act and eat, to lay up in summer sufficient provisions against the approaching winter. Some, I say, live in a different state; for having sufficiently fed, nourished, and bred up themselves to the perfection of their vermicular nympha state, in the summer months, they then retire to places of safety, and there throw off their nympha, and put on their aurelia, or chrysalis-state, for all the winter, in which there are no occasions for food. This is the constant method of many families of the insect-tribe (a).

(a) It would be endless to enter into particulars here, because all the papilionaceous, flesh, and ichneumon fly tribes, and all others that undergo the nympha and aurelia state, between that of the egg and the mature state, which are very numerous, appertain to this note. For a sample therefore only, I shall take what some may think a mean one, but if considered, deserves our admiration, and that is, the sagacity of the white-butterfly caterpillar, which having fed itself its due time, then retires to places of security. I have seen great trains of them creeping up the walls and posts of the next houses, where, with the help of some cob-webs, like filaments, they hang themselves to the ceilings, and other commodious places, and then become aureliae; in which state and places they hang secure from the wet and cold,

But there are others, and some of them in their most perfect state too, that are able to subsist in a kind of torpitude, or sleeping-state, without any food at all; by reason, as there is no action, so no waste of body, no expence of spirits, and therefore no need of food (*b*).

But for others that move and act, and need food, it is a prodigious instinct and foresight the Creator hath imprinted on them, to lay up sufficient food in summer for the winter's (*c*) necessities and occasions. And it is very pretty to see with what unwearied diligence all hands are at work for that purpose, all the

till the spring, and warmer months, when they are transmuted into butterflies.

(*b*) I shall not name any of the particular species of insects which live in this state, because they are very numerous, but only remark two things observable in their sagacity in this matter: 1. That they are not driven by stress of weather to their retirement, but seem as naturally to betake themselves thereto, as other animals do to rest and sleep. For before the approach of cold weather, towards the end of summer, we may see some kinds of them flocking together, in great numbers, within doors, as swallows do a little before they leave us, as if they were making ready for their winter's rest. 2. That every species betakes itself to a proper convenient receptacle; some under the waters, to the bottom of ponds; some under the earth, below the frost; some under timber, stone, etc. lying on the ground; some into hollow trees, or under the bark, or in the wood; some into warm and dry places; and some into dry alone.

(*c*) There are not many kinds that thus provide their food before-hand. The most remarkable, are the ant and the bee; concerning the first of which, Origen hath this remark, viz. 'De solertia formicarum, venturae hyemi mature prospicientium, sibi que invicem sub onere fessis succurrentium; quodque fruges arrosas condunt, ne rursus enascantur, sed per annum alimento sint, non ratiocinationem formicarum in causa debemus credere, sed almam matrem naturam bruta quoque sic ornantem, ut etiam minimis addat sua quaedam ingenia.' Orig. cont. Cels. l. 4.

But as for wasps, hornets, humble-bees, and other wild bees, vespaee-ichneumons, and divers others that carry in materials for nests and food; this is only for the service of their generation, for hatching their eggs, and nourishing their young, not for supplies in winter; for they all forsake their nests towards winter, and retire to other quarters, living, I conceive, without food all that time.

warmer months. Of this the holy scripture itself gives us an instance in the ant, calling that little animal 'exceeding wise,' Prov. xxx. 24. And the reason is, ver. 25. 'The ants are a people not strong, yet they prepare their meat in summer.' And therefore Solomon sends the sluggard to this little contemptible creature, to learn wisdom, foresight, care, and diligence, Prov. vi. 6, 7, 8. 'Go to the ant, thou sluggard, consider her ways, and be wise: which having no guide, overseer, or ruler, provideth her meat in the summer, and gathereth her food in the harvest.'

To this scriptural example, give me leave to anticipate and subjoin an observation of the farther great wisdom of this little creature; and that is their unparalleled *Στοργή*, their tenderness, sagacity, and diligence, about their young (*d*). It is very diverting,

(*d*) 'Hos vermiculos [formicarum ova vulgo vocatos] incredibili *Στοργή* et cura formicae educant, summamque dant operam, ne vel tantillum, quod spectet eorum vermiculorum educationem atque nutritionem, omittant: quem in finem semper eisdem ore circumportant secum, ne ulla eos laedat injuria. In museo meo nonnullas istius generis formicas, vitro terra repleto, conclusas cum vermiculis istis adservabam: ibi non sine jucunditate spectabam, quo terra fieret in superficie superior, eo profundius formicas cum foetibus suis praeperere. cum vero aquam adfunderem, visu mirificum erat, quanto affectu, quanta sollicitudine, quanta *Στοργή* omnem in eo collocarent operam, ut foetus suos sicciore et tuto loco reponerent. Saepius vidi, cum aliquot diebus aqua caruissent, atque cum affuso tantillo aquae terram illum humectarem, e vestigio a formicis foetus suos eo loci fuisse allatos, quos ibi distincte conspiciebam moveri atque fugere humorem. Multoties fui contentus, ut eos vermiculos ipse educarem, at semper conatum fessilem lit eventus: neque ipsas formicarum nymphas alimenti jam non indigas unquam sine ipsis formicis potui potu artificiali excludere.' J. Swammerd. Epilog. ad Hist. Insect. p. 153.

Sir Edward King, who was very curious in examining the generation of ants, observes their great care and diligence, 1. About their sperm, or true eggs, which is a fine white substance, like sugar, which they diligently gather into a heap, when scattered, and on which they lie in multitudes, I suppose, by way of incubation. 2. I have observed, saith he, in summer, that in the morning they bring up those of their young, called ant-eggs, toward the top of the bank; so that you may, from 10 in the morning, until 5 or 6 afternoon, find them near the top—for

as well as admirable to see, with what affection and care they carry about their young in their mouths, how they expose themselves to the greatest dangers, rather than leave their young exposed or forsaken; how they remove them from place to place in their little hills, sometimes to this part, sometimes to that, for the benefit of convenient warmth, and proper moisture; and then again withdraw, and guard them against rain and cold. Now, that this great wisdom which the scriptures attribute unto, and is discernible in this little animal, is owing only to the instinct, or infusions of the great Conservator of the world, is evident, because either this wisdom, thought, and forecast, is an act of the animal itself, or of some other being that hath wisdom. But the animal being irrational, it is impossible it can be its own act, but must be derived or received from some wise being. And who? what can that be, but the infinite Lord, Conservator, and Governor of all the world!

C H A P. VI.

Of the CARE of INSECTS about their YOUNG.

THE other notable instinct I am to treat of, is the peculiar art and care of the insect tribe, about the preservation of their species. Here I might speak of many things, but I have occasionally mentioned divers of them before, under some or other of the general heads, and therefore shall fix only upon two things relating to their special art and care about the production (a) of their young, which

the most part on the south side the bank. But towards 7 or 8 at night, if it be cool, or likely to rain, you may dig a foot deep before you can find them. Phil. Transf. No. 23. or Mr Lowthorp's Bridgm. vol. 2. pag. 7, and 9.

(a) The doctrine of equivocal generation, is at this day sufficiently exploded by all learned philosophers, that I shall not enter the dispute, but take it for granted, that all animals spring from other parent-animals. If the reader hath any doubt about

have not been so particularly spoken to as they deserve.

One thing is their singular providence for their young, in making or finding out such proper receptacles and places for their eggs and seed, as that they may receive the advantage of a sufficient incubation, and that the young when produced, may have the benefit of proper and sufficient food for their nurture and education, till they are able to shift for themselves. It is admirable to see with what diligence and care the several species of insects lay up their eggs, or sperm, in their several proper places; not all in the waters, in wood, or on vegetables; but those whose subsistence is in the waters (*b*), in the water; those to whom flesh is a proper food, in flesh (*c*);

it, I refer him to *Seigneur Redi de Gen. Insect.* and *Mr Ray's Wisdom of God*, etc. p. 344. See also before, book iv. chap. 15. note (*a*), p. 246.

(*b*) It would be endless to specify the various species of insects that have their generation in the waters: and therefore I shall only observe of them, 1. That their eggs are always laid up with great care, and in good order. And also, 2. Where proper and sufficient food is. 3. That in their nympha-state in the waters they have parts proper for food and motion; and in many, most of them, very different from what they have in their mature-state; a manifest argument of the Creator's wisdom and providence. For an instance, see note (*r*). p. 363.

(*c*) As *Seigneur Redi* was one of the first that made it his business to discard anomalous generation, so he tried more experiments relating to the vermination of serpents, flesh, fish, putrified vegetables; and, in short, whatever was commonly known to be the nursery of maggots, more, I say, probably, than any one hath done since. And in all his observations, he constantly found the maggots to turn to aureliae, and these into flies. He then, saith he, '*Dubitare coepi, utrum omne hoc vermium carne genus, ex solo muscarum semine, an ex ipsis putrefactis carnibus oriretur, tantoque magis confirmabar in hoc meo dogma, bio, quanto in omnibus generationibus—saepius videram in carnibus, antequam verminare inciperent, resedisse ejusdem speciei muscas, cujus propago postea nascebatur.*' Upon this he tells us, he put fish, flesh, etc. into pots, which he covered close from the flies with paper, and afterwards, for the free air-like with lawn, whilst other pots were left open, with such like flesh etc. in them; that the flies were very eager to get into the cover-

those to whom the fruits (*d*) or leaves of vegetables are food, are accordingly repositied, some in this fruit,

and pots; and that they produced not one maggot, when the open ones had many, Fr. Redi de Gener. Insect.

Among the insects that come from the maggots he mentions, he names culices. Now, from the most critical observations I have made, I never observed any sort of gnat to come from purified flesh, vegetables, or any other thing he taxeth them with. So that either he means by *culex*, some fly that we call not by the name of gnat; or else their gnats in Italy vary in their generation from ours in England. For among above thirty, near forty, distinct species of gnats that I have observed about the place where I live, I never found any to lay their eggs in flesh, fish, etc. but the largest sort, called by Aldrovand, *culices maximus*, by Swammerdam, *tipulae terrestres*, lay their eggs in meadows, etc. under the grass; one of the larger middle sort, in dead beer, yeast, etc. lying on the tops, or in the leaks of beer-barrels, etc. and all the rest, as far as ever I have observed, lay and hatch in the waters, as in note (*r*), p. 363.

The generation of the second of these being akin to some of the foregoing instances, and a little out of the way, may deserve a place here. This gnat lays its eggs commonly in dead beer, etc. as I said, and probably in vinegar, and other such liquors. Some time after which, the maggots are so numerous, that the whole liquor stirreth as if it was alive; being full of maggots, some larger, some smaller; the larger are the offspring of our gnat, the smaller, of a small dark coloured fly, tending to reddish, frequent in cellars, and such obscure places. All these maggots turn to *aureliae*, the larger of which, of a tan colour, turn to our gnat. This gnat is of the unarmed kind, having no spear in its mouth: its head is larger than of the common gnats, a longer neck, short-jointed antennae, spotted wings, reaching beyond its tender alvus; it is throughout of a brown colour, tending to red, especially in the female: the chief difference between the male and female is, as in other gnats, yea, most insects, the male is less than the female, and hath a slenderer belly, and its podex not so sharp as the female's is.

(4) The insects that infest fruits, are either of the *ichneumon*-kind, or *phalaenae*. Plumbs, pease, nuts, etc. produce some other *ichneumon*-fly. That generated in the plumb is black, of middle size, its body near three tenths of an inch long, its tail not much less, consisting of three bristles, wherewith it conveys its eggs into fruits: its antennae, or horns, long, slender, reerved; its belly longish, tapering, small towards the thorax; its eggs reddish; wings membranaceous, thin, and transparent, Numb. 4. which is one characteristic of the *ichneumon*-fly.

The pease *ichneumon*-fly is very small, wings large, reaching beyond the podex; antennae long; alvus short, shaped like an heart, with the point towards the anus; it walketh and flieth slow-

some on this tree (*e*), some on that plant (*f*), some on another, and another; but constantly the same family on the same tree or plant, the most agreeable to that family. And as for others that require a constant and greater degree of warmth, they are accordingly provided by the parent-animal with some place in or about the body of other animals; some in the

ly: no tail appears as in the former; but they have one lying hidden under the belly, which they can at pleasure bend back to pierce pease when they are young and tender, and other things also, as I have reason to suspect, having met with this, as indeed the former two, in divers vegetables.

Pears and apples I could never discover any thing to breed in, but only the lesser phalaena, about four tenths of an inch long, whitish underneath, greyish-brown above, dappled with brown spots, inclining to a dirty red, all but about a third part at the end of the wings, which is not grey, but brown, elegantly striped with wavy lines, of a gold colour, as if gilt; its head small, with a tuft of whitish brown in the forehead; antennae smooth, moderately long. The aurelia of this moth is small, of a yellowish brown. I know not what time they require for their generation out of boxes; but those I laid up in August, did not become moths before June following.

(*e*) There are many of the phalaenae, and ichneumon-fly tribe that have their generation on the leaves, or other parts of trees and shrubs, too many to be here reckoned up. The oak has many very beautiful phalaenae, bred in its convolved leaves, white, green, yellow, brown, spotted prettily, and neatly dappled, and many more besides; and its buds afford a place for caterpillars and balls of various sorts, as shall be shewn hereafter; its leaves expanded, minister to the germination of globular, and other spheroidical balls, and flat thecae, some like hats, some like buttons excavated in the middle; and divers other such like repositories, all belonging to the ichneumon-fly kind. And not only the oak, but the mapple also, the white-thorn, the brier, privet, and indeed almost every tree and shrub.

(*f*) And as trees and shrubs, so plants have their peculiar insect. The white butterfly lays its voracious offspring on cabbage leaves; a very beautiful reddish ocellated one; its no less voracious black offspring, of an horrid aspect, on the leaves of nettles; as also doth a very beautiful, small greenish ichneumon-fly, in cases on the leaves of the same plant: and to name no more, because it would be endless, the beautiful rag-worth moth, whose upper wings are brown, elegantly spotted with red, and under wings edged with brown; these, I say, provide for the golden-ringed crucae upon the ragwort-plant.

athers of birds (*g*); some in the hair of beasts (*h*);
 some in the very scales of fishes (*i*); some in the nose (*k*);

(*g*) Many, if not most sorts of birds, are infested with a distinct kind of lice, very different from one another in shape, size, &c. For figures and descriptions of them, I shall refer to *Seigneur Redi of Insects*. See also *Mouffet*, l. 2. c. 23. These lice are hatched among the feathers of the respective birds, where they are hatched and nourished; and, as *Aristotle* saith, would destroy the birds, particularly pheasants, if they did not dust their feathers. *Loco infra citat.*

(*h*) And as birds, so the several sorts of beasts have their peculiar sorts of lice; all distinct from the two sorts infesting man: by the ass, they say, is free, because our Saviour rode upon it, as some think; but I presume it is rather from the passage *Pliny*, l. 11. c. 33. or rather *Arist.* *Hist. Animal.* l. 3. c. 31. who saith, 'Quibus pilus est, non carent eodem [pediculo] excepto asino, qui non pediculo tantum, verum etiam redivio immunis est.' And a little before, speaking of those in men, he shews what constitutions are most subject to them, and instanceth *Aleman* the poet, and *Pherecydes Syrius*, that died of the scab, or lowly disease. For which foul distemper, if medicines are desired, *Mouffet de Insect.* p. 262. may be consulted; so, in the same page, hath this observation, 'Animadverterunt Coltrates—ubi Afores insulas a tergo reliquerint, pediculos confestim omnes tabescere: atque ubi eos reviserint, iterum innumeros alios subito oriri.' Which observation is confirmed *Dr Stubbs*. Vide *Lowth.* *Abridgm.* vol. 3. p. 558. And many men have told me the same.

(*i*) Fishes, one would think, should be free from lice, by reason they live in the waters and are perpetually moving in, and passing through them; but yet they have their sorts too. Besides which, I have frequently found great numbers of long slender worms in the stomachs, and other parts of fish, particularly codfish, especially such as are poor; which worms have worked themselves deeply into the coats and flesh, so that they could easily be gotten out: so *Aristotle* saith of some fishes, 'Balro et tilloni lumbricus innascitur, qui debilitat, etc. Chalcis itio infestatur diro, ut pediculi sub branchiis innati quam multum interimant.' *Hist. An.* l. 8. c. 20.

(*k*) Of insects bred in the nose of animals, those in the nostrils of man are remarkable. I have myself taken out not fewer at a time than twenty or thirty rough maggots, lying among the laminae of the nostrils. But I could never hatch any of them, and so know not what animal they proceed from: but I have no great doubt, they are of the ichneumon-fly kind; and not improbably of that which has a long tail, called trifeta, whose three bristles seem very commodious for conveying their eggs into deep places.

I have also seen a rough whitish maggot, above two inches long, in the intestinum rectum of horses, firmly adhering thereto,

some in the flesh (l) ; yea, some in the very

that the hard dung did not rub off. I never could bring them to perfection, but suspect the side fly proceeds from it.

(l) In the backs of cows, in the summer-months, there are maggots generated, which in Essex we call wornils; which are first only a small knot in the skin; and, I suppose, no other than an egg laid there by some insect. By degrees these knots grow bigger, and contain in them a maggot lying in a purulent matter: they grow to be as large as the end of one's finger, and may be squeezed out at a hole they have always open: they are round and rough, and of a dirty white. With my utmost endeavour and vigilance, I could never discover the animal that turn into; but as they are somewhat like, so may be the same as those in the note before.

In Persia, there are very long slender worms, bred in the legs and other parts of mens bodies, 6 or 7 yards long.

In Philosophical Transactions, Mr Dent, and Mr Lewis, relate divers examples of worms taken out of the tongue, gums, nose, and other parts, by a woman at Leicester, which they were eye witnesses of. These, and divers others mentioned in the Transactions, may be seen together in Mr Lowthorp's Abridgement vol. 3. p. 132.

‘ Narrat mihi vir sive dignus—Casp. Wendlant—se in Persia, puero cuidam rustico duorum annorum, vermiculum ab oculo palpebra extraxisse,—magnitudinis Erucae—Simile sere huic casum mihi [Schulzio] et D. Segero narravit hoc Anno 1676, chirurgus noster Ant. Statlender, qui cuidam puero, ex auro, extraxit vermiculum talem, qualis in nocio avellanis perforatis latitare solet, sed paulo majorem, colore albidissimi; alteri minores ejusdem generis similiter ex auribus omnes aliquot horas supervixerunt—vermiculos adhuc vivos oculis nostris vidimus.’ Ephem. Germ. T. 2. obs. 24. vermiculi Icon. Many other instances may be met with in the same tome. Obs. 147. 148 154.

The worms in deer are mentioned often among ancient writers. Aristotle saith, Σώληνας μέντοι πάντες ἔχουσιν, ἐν τῇ κεφαλῇ, etc. ‘ They [deer] all have live-worms in their heads, bred under the tongue, in a cavity near the vertebrae, which the head is placed; their size not less than of the greatest maggots; they are bred all together, in number about twenty.’ Aristot. Hist. Animal. l. 2. c. 15.

To these examples may be added the generation of the ichneumon-fly in the bodies of caterpillars, and other nymphae of insects. In many of which, that I have laid up to be hatched in boxes, instead of papilios etc. as I expected, I have found a great number of small ichneumon-flies, whose parent-animal had wounded those nymphae, and darted its eggs into them, and made them the foster-mother of its young. More particulars of this way of generation may be seen in the great Mr Willoughby

vowels (*m*), and inmost recesses of the bodies of man and other creatures (*n*): and as for others, to whom

observations in Philos. Trans. No. 76. But concerning the farther generation of this insect, I have taken notice of other particulars in other places of those notes.

(*m*) The animals ordinarily bred in the stomach and guts, are the three sorts of worms called *lati*, *teretes*, and *ascarides*; concerning which, it would be irksome to speak in particular, and therefore I shall refer to *Mouffet*, lib. 2. cap. 31. 32. 33. Dr *Wyllon's* anatomy of them in Mr *Lowthorp's* Abridgement, vol. 3. p. 121. *Seigneur Redi's* obs. and others that have written of them.

As not only worms, but other creatures also are said to be found in the stomach; instances of which are so innumerable, that I shall only select a few related by persons of the best credit. And first of all, by some of our own countrymen. Dr *Lifter*, whose credit and judgement will hardly be questioned, gives an account of true caterpillars, vomited up by a boy of nine years old: and another odd animal by a poor man. Mr *Jessop*, another very judicious, curious and ingenious gentleman, saw hexapods vomited up by a girl; which hexapods lived and fed for five weeks. See *Lowth. ib.* p. 135.

As to foreigners, it is a very strange story, but attested by persons of great repute, of *Catharina Geileria*, that died in Feb. 1662, in the hospital of *Altenburg*, in Germany, who, for twenty years, voided by vomit and stool, toads and lizzards, etc. *Ephemer. Germ. T. 1. obs. 103.* See also the 109th observation of a kitten bred in the stomach, and vomited up; of whelps also, and other animals, bred in like manner. But I fear a stretch of fancy might help in some of those last instances, in those days when spontaneous generation was held, when the philosophers seem to have more slightly examined such appearances than now they do. But for the breeding of frogs or toads, or *lacertae aquaticae*, in the stomach, when their spawn happeneth to be drank, there is a story in the second tome of the *Ephem. Germ. obs. 56.* that favours it, viz. 'In the year 1667, a butcher's man going to buy some lambs in the spring, being thirsty, drank greedily of some standing water, which, a while after, caused great pains in his stomach, which grew worse and worse, and ended in dangerous symptoms. At last he thought somewhat was alive in his stomach, and after that, vomited up three live toads; and so recovered his former health.'

Such another story Dr *Sorbait* tells, and avoucheth it seen with his own eyes, of one that had a toad came out of an abscess, which came upon drinking foul water. *Obs. 103.*

(*n*) Not only in the guts, and in the flesh, but in many other parts of the body, worms have been discovered. One was voided by urine, by Mr *Mat. Milford*, supposed to have come from the kidneys. *Lowth. ib.* p. 135. More such examples *Mouffet*

none of these methods are proper, but make themselves nests by perforations in the earth, in wood, or combs they build, or such like ways; it is admirable to see with what labour and care they carry in, and seal up provisions, that serve both for the production of their young, as also for their food and nurture when produced (o).

The other piece of remarkable art and care about the production of their young, is their curiosity and

tells of. Ibid. So the vermes cucurbitini are very common in the vessels in sheeps livers. And Dr Lister tells of them, found in the kidney of a dog, and thinks that the snakes and toads, etc. said to be found in animals bodies, may be nothing else. Lowth. ib. p. 120. Nay, more than all this: in Dr Bern. Verzaschari's sixth observation, there are divers instances of worms bred in the brain of man. One, a patient of his, troubled with a violent headache, and an itching about the nostrils, and frequent sneezing, who, with the use of a sneezing-powder, voided a worm, with a great deal of snot from his nose. A like instance he gives from Bartholine, of a worm voided from the nose of O. W. which he guisseth was the famous Olaus Wormius: another, from a country-woman of Dietmarsh; and others in Tulpus, F. Hildanus, Schenckius, etc. These worms he thinks are undoubtedly bred in the brain: but what way they can come from thence, I cannot tell. Wherefore I rather think, they are such worms as are mentioned in note (k), p. 359.; and even that worm that was actually found in the brain of the Paris girl, when opened, I guess might be laid in the laminae of the nostrils, by some of the ichneumon or other insect kind, and might gnaw its way into the brain, through the os cribriforme. Of this he tells us from Bartholine, 'Tan-
 * dem cum tabida obiisset, statim aperto cranio praesentes medic-
 * totam cerebelli substantiam, quae ad dextrum vergit, a reliqua
 * corpore sejunctam, nigraque tunica involutam deprehenderunt
 * haec tunica rupta, latentem vermem vivum, et pilosum, duobus
 * punctis splendidis loco oculorum prodidit, ejusdem fere mol-
 * cum reliqua cerebri portione, qui duarum horarum spatio sa-
 * pervixit.' B. Verzas. Obs. Medicae, p. 16.

Hildanus tells us such another story, viz. 'Filius Theod. an-
 * der Roulen, Avunculi mei, diuturno vexabatur dolore capitis
 * —Deinde febricula et sternutatione exorta, ruptus est abscessus
 * sus circa os cribriforme—et vermis prorepsit.' By his figure
 of it, the maggot was an inch long, and full of bristles. Fals.
 Hildan. Cent. 1. obs.

Galenus Wierus, physician to the Princ. Jul. et. Cleve, he said told him, that he had, at divers times, found worms in the gas-
 bladder in persons he had opened at Dusseldorp. Id. ib. obs. 60.

(o) See before, book iv. chap. 13. note (c), p. 232.

heatness in repositing their eggs, and in their nidification.

As to the first of which, we may observe, that great curiosity and nice order is generally observed by them in this matter. You shall always see their eggs laid carefully and commodiously up (*p*). When upon the leaves of vegetables, or other materials on hand, always glued thereon with care, with one certain end lowermost, and with handsome juxtapositions (*q*). Or if in the waters, in neat and beautiful rows oftentimes, in that spermatic, gelatine matter, in which they are repositied, and that matter carefully tied and fastened in the waters, to prevent its dissipation (*r*); or if made to float, so carefully spread

(*p*) Some insects lay up their eggs in clusters, as in holes of earth, and such places, where it is necessary they should be crowded together; which, no question, prevents their being too much dried up in dry places, and promotes their hatching. But,

(*q*) As for such as are not to be clustered up, great order is used. I have seen upon the posts and sides of windows, little round eggs resembling small pearl, which produced small hairy caterpillars, that were very neatly and orderly laid. And, to name no more, the white butterfly lays its neat eggs on the cabbage leaves in good order, always gluing one certain end of the egg to the leaf. I call them neat eggs, because if we view them in a microscope, we shall find them very curiously furrowed, and handsomely made and adorned.

(*r*) By reason it would be endless to specify the various generation of insects in the water, I shall therefore, because it is little observed, take Pliny's instance of the gnat, a mean and contemned animal, but a notable instance of nature's work, as he saith.

The first thing considerable in the generation of this insect, is, for the size of the animal, its vast spawn, being some of them above an inch long, and half a quarter diameter; made to float in the water, and tied to some stick, stone, or other fixed thing in the waters, by a small stem, or stalk. In this gelatine, transparent spawn, the eggs are neatly laid; in some spawns in a single, in some in a double spiral line, running round from end to end, as in Fig. 9, and 10; and in some transversely, as in Fig. 8.

When the eggs are by the heat of the sun, and warmth of the season, hatched into small maggots, these maggots descend to the bottom, and by means of some of the gelatine matter of the spawn, which they take along with them, they stick to stones and other bodies at the bottom, and there make themselves little

and poised, as to swim about with all possible artifice.

And as to their other faculty, that of nidification, whether it be exerted by boring the earth or wood, or building themselves cells (*f*), or spinning and weaving themselves cases and webs, it is all a wonderful faculty of those poor little animals, whether we consider their parts wherewith they work, or their work itself. Thus those who perforate the earth, wood, or such like, they have their legs, feet, mouth, yea, and whole body, accommodated to that service; their mouth exactly formed to gnaw those handsome round holes, their feet, as well made to scratch and

cases or cells, which they creep into and out of at pleasure, until they are arrived to a more mature nympha-state, and can swim about here and there, to seek for what food they have occasion; at which time, they are a kind of red worms, above half an inch long, as in Fig. 11.

Thus far this mean insect is a good instance of the divine providence towards it. But if we farther consider, and compare the three states it undergoes after it is hatched, we shall find yet greater signals of the Creator's management, even in these meanest of creatures. The three states I mean, are its nympha-vermicular state, its aurelia, and mature state, all as different as to shape and accoutrements, as if the insect was three different animals. In its vermicular state, it is a red maggot, as I said, and hath a mouth and other parts accommodated to food. In its aurelia-state, it hath no such parts, because it then subsists without food; but in its mature, gnat-state, it hath a curious well made spear, to wound and suck the blood of other animals. In its vermicular state, it hath a long worm-like body, and something analogous to fins or feathers, standing erect near its tail, and running parallel with the body; by means of which resisting the waters, it is enabled to swim about by curvations, or flapping its body side-ways, this way and that, as in Fig. 12.

But in its aurelia-state, it hath a quite different body, with a club-head, (in which the head, thorax, and wings of the gnat are inclosed), a slender alvus, and a neat finny tail, standing at right angles with the body, quite contrary to what it was before; by which means, instead of easy flapping side-ways, it swims by rapid, brisk jirks, the quite contrary way; as is in some measure represented in Fig. 13. But when it becomes a gnat, no finny tail, no club-head, but all is made in the most accurate manner for flight and motion in the air, as before it was for the waters.

(*f*) See book iv. chap. 13. notes (*n*), (*o*), p. 237.

bore (*s*), and their body handsomely turned and fitted to follow. But for such as build or spin themselves nests, their art justly bids defiance to the most ingenious artist among men, so much as tolerably to copy the nice geometrical combs of some (*t*), the earthen cells of others, or the webs, nets, and cases (*u*) woven by others. And here that natural glue (*x*) which

(*s*) Thus the mouths and other parts of the ichneumon-wasps, in book iv. chap. 13. note (*c*), p. 232. So the feet of the gylotalpa, *ibid.* note (*f*), p. 237.

(*t*) See the last cited places, note (*o*), p. *ibid.*

(*u*) Of the textrine art of the spider, and its parts serving to that purpose, see the last cited place, note (*v*), p. 239.

Besides these, caterpillars, and divers other insects, can emit threads, or webs, for their use. In this their nympha-state, they secure themselves from falling, and let themselves down from the boughs of trees, and other high places, with one of these threads. And in the cases they weave, they secure themselves in their aurelia-state.

And not only the offspring of the phalaena-tribe, but there are some of the ichneumon-fly kind also, endowed with this textrine art. Of these I have met with two sorts; one that spun a milk-white, long, round, silken web, as big as the top of one's finger, not hollow within, as many are, but filled throughout with silk. These are woven round bents, stalks of ribwort, etc. in meadows. The other is a lump of many yellow, silken cases, sticking confusedly together on posts, under coleworts, etc. These webs contain in them small, whitish maggots; which turn to a small, black ichneumon-fly, with long, capillary antennae; tan coloured legs; long wings reaching beyond their body, with a black spot near the middle; the alvus like an heart; and in some, a small setaceous tail. Some of these flies were of a shining, beautiful green colour. I could not perceive any difference, at least not specifical, between the flies coming from those two productions.

(*x*) I have often admired how wasps, hornets, ichneumon-wasps, and other insects that gather dry materials for building their nests, have found a proper matter to cement and glue their combs, and line their cells; which we find always sufficiently context and firm. But in all probability, this useful material is in their own bodies; as it is in the tinea vestivora, the cadeworm, and divers others. Goedart observes of his *eruca*, Num. xx. 6. that fed upon fallow-leaves, that it made its cell of the comminuted leaves, glued together with its own spittle. 'Haec pulveris aut arenae instar comminuit, ac pituitoso quodam sui corporis succo ita maceravit, ut inde accommodatum subeundae mutationi instanti locum sibi extruxerit. Domuncula haec a

their bodies afford some of them to consolidate their work, and combine its materials together, and which in others can be darted out at pleasure, and spun and woven by them into silken balls (y) or webs: I say, this so peculiar, so serviceable a material, together with the curious structure of all parts ministering to this textrine power, as mean a business as it may seem, is such as may justly be accounted among the noble designs and works of the infinite Creator and Conservator of the world.

In the last place, there is another prodigious faculty, art, cunning, or what shall I call it? that others of those little animals have, to make even nature itself serviceable to their purpose; and that is, the making the vegetation and growth of trees and plants, the very means of the building of their little nests and cells (z), such as are the galls and balls

‘communi salicis ligno nihil differre videbatur, nisi quod longe essent durior, adeo ut cultro vix dirumpi posset.’

(y) ‘An ingenious gentlewoman of my acquaintance, wife to a learned physician, taking much pleasure to keep silk-worms, had once the curiosity to draw out one of the oval cases, which the silk-worm spins—into all the silken-wire it was made up of, which to the great wonder as well of her husband, as herself,—appeared to be, by measure, a great deal above 300 yards, and yet weighed but two grains and an half.’ Boyle Subtil. of Effluv. chap. 2.

(z) Since my penning this, I have met with the most sagacious Malpighi’s account of galls, etc. and find his descriptions to be exceedingly accurate and true, having traced myself many of the productions he hath mentioned. But I find Italy and Sicily (his book de Gallis being published long after he was made professor at Messina) more luxuriant in such productions than England, at least than the parts about Upminster, where I live, are. For many, if not most of those about us, are taken notice of by him, and several others besides that I never met with; although I have, for many years, as critically observed all the excrescences, and other morbid tumours of vegetables, as is almost possible, and do believe that few of them have escaped me.

As to the method how those galls and balls are produced, the most simple, and consequently the most easy to be accounted for, is that in the gems of oak, which may be called squamous oak-cones, capitula squamata, in Malpighi: whose description not exactly answering our English cones in divers respects, I shall

found on the leaves and branches of divers vegetables, such as the oak, the willow (*aa*), the briar, and some others.

Therefore pass his by, and shew only what I have observed myself concerning them.

These cones are, in outward appearance, perfectly like the gems, only vastly bigger; and indeed they are no other than the gems, increased in bigness, which naturally ought to be pushed out in length: the cause of which obstruction of the vegetation is this: into the very heart of the young tender gem or bud which begins to be turgid in June, and to shoot towards the latter end of that month, or beginning of the next; into this, I say, the parent-insect thrusts one or more eggs, and not perhaps without some venomous ichor therewith. This egg soon becomes a maggot, which eats itself a little cell in the very heart or pith of the gem, which is the rudiment of the branch, together with its leaves and fruit, as shall be hereafter shewn. The branch being thus wholly destroyed, or at least its vegetation being obstructed, the sap that was to nourish it, is diverted to the remaining parts of the bud, which are only the scaly teguments; which by these means grow large and flourishing, and become a covering to the insect-case, as before they were to the tender branch and its appendage.

The case lying within this cone, is at first but small, as the maggot included in it is; but by degrees, as the maggot increaseth, so it grows bigger, to about the size of a large white pea-seed, long and round, resembling the shape of a small acorn.

The insect itself is, according to the modern insectologers, of the ichneumon-fly kind, with four membranaceous wings, reaching a little beyond the body, articulated horns, a large thorax, bigger than the belly; the belly short and conical, much like the heart of animals; the legs partly whitish, partly black. The length of the body from head to tail, about two tenths of an inch; its colour, a very beautiful shining green, in some tending to a dark copper colour. Figures both of the cones, cases, and insects, may be seen among Malpighi's cuts of galls, Tab. 13. and Tab. 20. Fig. 72. which Fig. 72. exhibits well enough some others of the gall-insects, but its thorax is somewhat too short for ours.

(*aa*) Not only the willow, and some other trees, but plants also, as nettles, ground ivy, etc. have cases produced on their leaves, by the injection of the eggs of an ichneumon-fly. I have observed those cases always to grow in, or adjoining to some rib of the leaf, and their production I conceive to be thus, viz. the parent-insect, with its stiff setaceous tail, terebrates the rib of the leaf, when tender, and makes way for its egg into the very pith or heart thereof, and probably lays in therewith, some proper juice of its body, to pervert the regular vegetation of it. From this wound arises a small excrescence, which, when

Now, this is so peculiar an artifice, and so far out of the reach of any mortal understanding, wit, or power, that if we consider the matter, with some of its circumstances, we must needs perceive manifest design, and that there is the concurrence of some great and wise Being, that hath from the beginning, taken care of, and provided for the animal's good: for which reason, as mean as the instance may seem, I might be excused, if I should enlarge upon its particulars. But two or three hints shall suffice.

In the first place, it is certain, that the formation of those cases and balls quite exceeds the cunning of the animal itself; but it is the act partly of the vegetable, and partly of some virulency, (or what shall I call it?) in the juice, or egg, or both, deposited on the vegetable by the parent-animal (*bb*),

the egg is hatched into a maggot, grows bigger and bigger, as the maggot increases, swelling on each side the leaf between the two membranes, and extending itself into the parenchymous part thereof, until it is grown as big as two grains of wheat. In this case lies a small, white, rough maggot, which turns to an aurelia, and afterwards to a very beautiful green, small ichneumon-fly.

(*bb*) What I suspected myself, I find confirmed by Malpighi, who, in his exact and true description of the fly bred in the oaken galls, saith, 'Non sat fuit naturae tam miro artificio terebram seu limam condidisse; sed inflicto vulnere, vel excitato foramine infundendum exinde liquorem intra terebram condidit: quare fracta per transversam muscarum terebra frequentissime, vivente animali, guttae aliquot diaphani humoris effluunt.' And a little after, he confirms by ocular observation, what he imagined before, viz. 'Semel prope Junii finem mide muscam, qualem superius delineavi, insidentem quercinae gemmae, adhuc germinanti; haerebat etenim foliolo stabili ab apice hiantis gemmae erumpenti: et convulso in arcum corpore, terebram evaginabat, ipsamque tensam immittebat; et tumefacto ventre circa terebrae radicem tumorem excitabat, quem interpolatis vicibus remittebat. In folio igitur, avulsa musca, minima et diaphana reperi ejecta ova, simillima iis, quae adhuc in tubis supererant. Non licuit iterum idem admirari spectaculum,' etc.

Somewhat like this, which Malpighi saw, I had the good fortune to see myself once, some years ago: and that was the beautiful, shining oak-ball ichneumon strike its terebra into an oak-apple divers times, no doubt to lay its eggs therein. And hence I apprehend we see many vermicules towards the outside of

And as this virulency is various, according to the difference of its animal, so is the form and texture of the cases and balls excited thereby; some being hard shells (*cc*), some tender balls (*dd*), some scaly (*ee*);

many of the oak-apples, which I guess were not what the primitive insects laid up in the gem, from which the oak-apple had its rise, but some other supervenient, additional insects, laid in after the apple was grown, and whilst it was tender and soft.

(*cc*) The Aleppo-galls, wherewith we make ink, may be reckoned of this number, being hard, and no other than cases of insects which are bred in them; who, when come to maturity, gnaw their way out of them; which is the cause of those little holes observable in them. Of the insects bred in them, see *Philos. Trans.* No. 245. Of this number also are those little smooth cases, as big as large pepper corns, growing close to the ribs under oaken-leaves, globous, but flattish; at first touched with a blushing red, afterwards growing brown, hollow within, and an hard thin shell without. In this lieth commonly a rough, white maggot, which becomes a little long winged, black ichneumon-fly, that eats a little hole in the side of the gall, and so gets out.

(*dd*) For a sample of the tender balls, I shall chuse the globous ball, as round, and some as big as small musket-bullets, growing close to the ribs, under oaken-leaves, of a greenish yellowish colour, with a blush of red; their skin smooth, with frequent rings therein. Inwardly they are very soft and spongy; and in the very centre is a case with a white maggot therein, which becomes an ichneumon-fly, not much unlike the last. As to this ball, there is one thing I have observed somewhat peculiar, and I may say providential, and that is, that the fly lies all the winter in these balls in its infantile-state, and comes not to its maturity till the following spring. In the autumn, and winter, these balls fall down with their leaves to the ground, and the insect inclosed in them is there fenced against the winter frosts, partly by other leaves falling pretty thick upon them, and especially by the thick parenchymous, spongy walls, afforded by the galls themselves.

Another sample shall be the large oak-balls, called oak-apples, growing in the place of the buds, whose generation, vegetation, and figure, may be seen in *Malpig. de Gallis*, p. 24. and *Tab. 10.* fig. 33, etc. Out of these galls, he saith, various species of flies come, but he names only two, and they are the only two I ever saw come out of them: 'Frequenter,' saith he, 'subnigrae sunt muscae brevi munitae terebrae. Inter has aliquae observantur aureae, levi viridis tinctura suffusae, oblonga pollentes terebrae.' These two differently coloured flies I take to be no other than male and female of the same species. I have not observed tails, which are their terebrae, in all, as Malpighi seems to intimate:

some smooth (*ff*), some hairy (*gg*), some long, some round, some conical, etc. (*hh*). And in the last

perhaps they were hid in their thecae, and I could not discover them: but I rather think there were none, and that those were the males: but in others, I have observed long, recurvous tails, longer than their whole bodies; and these I take to be the females. And in the oak-apples themselves, I have seen the aureliae, some with, some without tails. And I must confess, it was not without admiration, as well as pleasure, that I have seen with what exact neatness and artifice, the tail hath been wrapt about the aurelia, whereby it is secured from either annoying the insect, or being hurt itself.

(*ee*) See before, note (*z*), p. 366.

(*ff*) As in the preceding note.

(*gg*) Of the rough or hairy excrescences, those on the briar, or dog-rose, are a good instance. These spongiolae villosae, as Mr Ray, gallae rumosae, as Dr Malpighi calls them, are thus accounted for by the latter; 'Ex copiosis relictis ovis ita turbatur affluens [rubi] succus, ut strumosa fiant complura tubercula simul confuse congesta, quae utriculorum seribus, et fibrarum implicatione contexta, ramosas propagines germinant, ita ut minima quasi sylva appareat. Quaelibet propago ramos, hinc inde villosos edit. Hinc inde pilae pariter erumpunt,' etc.

These balls are a safe repository to the insect all the winter in its vermicular-state. For the eggs laid up, and hatched the summer before, do not come to mature insects until the spring following, as Mr Ray rightly observes in Cat. Cantab.

As to the insects themselves, they are manifestly ichneumon-flies, having four wings, their alvus thick and large towards the tail; and tapering up till it is small and slender at its setting on to the thorax. But the alvi, or bellies, are not alike in all, though coloured alike. In some they are as is now described, and longer without terebrae, or tails; in some shorter, with tails; and in some yet shorter, and thick, like the belly of the ant, or the heart of animals, as in those before, note (*z*), p. 366. But for a farther description of them, I shall refer to Mr Ray, Cat. Plantarum circa Cantab. under Rosa sylvest.

(*hh*) It being an instance somewhat out of the way, I shall pitch upon it for an example here, viz. the gouty swellings in the body, and the branches of the black-berry bush; of which Malpighi hath given us two good cuts in Tab. 17. Fig. 62. The cause of these is manifestly from the eggs of insects laid in, while the shoot is young and tender, as far as the pith, and in some places not so deep: which, for the reasons before mentioned, makes the young shoots tumify, and grow knotty and gouty.

The insect that comes from hence is of the former tribe, a small shining, black ichneumon-fly, about a tenth of an inch long, with jointed, red, capillary horns, four long wings, reaching beyond the body, a large thorax, red legs, and a short heart-like belly.

place, let us add, that those species of insects are all endowed with peculiar and exactly made parts for this service, to bore and pierce the vegetable, and to reach and inject their eggs and juice into the tender parts thereof.

The Conclusion.

AND now, these things being curiously considered, what less can be concluded, than that there is manifest design and forecast in this case, and that there must needs be some wise Artist, some careful, prudent Conservator, that from the very beginning of the existence of this species of animals, hath, with great dexterity and forecast, provided for its preservation and good ! For what else could contrive and make such a set of curious parts, exactly fitted up for that special purpose ; and withal implant in the body such peculiar impregnations, as should have such a strange uncouth power on a quite different rank of creatures ? And lastly, what should make the insect aware of this its strange faculty and power, and teach it so cunningly and dextrously to employ it for its own service and good !

They hop like fleas. The males are less than the females ; are very venereous, endeavouring a coit in the very box in which they are hatched : getting up on the females, and tickling and thumping them with their breeches and horns to excite them to venery.

BOOK IX.

Of REPTILES and the INHABITANTS of the WATERS.

CHAP. I.
Of REPTILES.

HAVING dispatched the insect-tribe, there is but one genus of the land-animals remaining to be surveyed, and that is, that of reptiles (a). Which I shall dispatch in a little

(a) Notwithstanding I have before, in book iv. chap. 12. note (p) p. 228. taken notice of the earth-worm; yet it being a good example of the Creator's wise and curious workmanship, in even this meanest branch of the creation, I shall superadd a few farther remarks from Drs Willis and Tyson. Saith Willis, 'Lumbricus terrestris, licet vile et contemptibile habetur, organa vitalia, necnon et alia viscera et membra divino artificio admirabiliter fabricata fortitur: totius corporis compages musculorum annularium catena est, quorum fibrae orbiculares contractae quaeque annulum, prius amplum, et dilatatum, angustiores et longiores reddunt.' [This muscle in earth-worms I find is spirally as in a good measure is their motion likewise; 'so that by this means they can, like the worm of an augre, the better bore their passage into the earth. Their reptile motion also may be explained by a wire wound on a cylinder, which when slipped off, and one end extended and held fast, will bring the other near it. So the earth-worm, having shut out, or extended its body, which is with a wreathing, it takes hold by those small feet it hath, and so contracts the hinder part of its body. Thus the curious and learned Dr Tyson, Philos. Transf. No. 147. Nam proinde cum corporis portio superior elongata, et exposita recta, ad spatium alterius extenditur, ibidemque plano affigitur ad ipsum quasi ad centrum portio corporis inferior relaxata, et abbreviata facile pertrahitur. Pedunculi serie quadruplici, per totam longitudinem lumbrici disponuntur; his quasi totidem uncis, partem modo hanc, modo istam, plano affigit, dum alteram exporrigit, aut post se ducit. Supra oris hiatum, proboscide, qua terram perforat et elevat, donatur.' And then he goes on with the other parts that fall under view, the brain, the gullet, the heart, the spermatic vessels, the stomachs and intestines, the foramina on the top of the back, adjoining to each

compass, by reason I have somewhat amply treated of others, and many of the things may be applied here. But there are some things in which this tribe is somewhat singular, which I shall therefore take notice of briefly in this place. One is their motion, which I have in another place (*b*) taken notice of to be not less curious, than it is different from that of other animals, whether we consider the manner of it, as vermicular, or sinuous (*c*), or like that of the snail (*d*), or the caterpillar (*e*), or the multipedous (*f*), or

ring, supplying the place of lungs, and other parts. Willis de Anim. Brut. p. 1. c. 3.

(*b*) In book iv. chap. 8.

(*c*) There is a great deal of geometrical neatness and nicety, in the sinuous motion of snakes, and other serpents. For the assisting in which action, the annular scales under their body are very remarkable, lying cross the belly, contrary to what those on the back, and the rest of the body do; also as the edges of the foremost scales lie over the edges of their following scales, from head to tail; so those edges run out a little beyond, or over their following scales; so as that when each scale is drawn back, or set a little upright, by its muscle, the outer edge thereof, or foot it may be called, is raised also a little from the body, to lay hold on the earth, and so promote and facilitate the serpent's motion. This is what may be easily seen in the slough, or belly of the serpent-kind. But there is another admirable piece of mechanism, that my antipathy to those animals hath prevented my prying into; and that is, that every scale hath a distinct muscle, one end of which is tacked to the middle of its scale; the other, to the upper edge of its following scale. This Dr Tyson found in the rattle-snake, and I doubt not is in the whole tribe.

(*d*) The wise Author of nature, having denied feet and claws to enable snails to creep and climb, hath made them amends in a way more commodious for their state of life, by the broad skin along each side of the belly, and the undulating motion observable there. By this latter it is they creep; by the former, assisted with the glutinous slime emitted from the snail's body, they adhere firmly and securely to all kinds of superficies, partly by the tenacity of their slime, and partly by the pressure of the atmosphere. Concerning this part, which he calls the snail's feet, and their undulation, see Dr Lister's Exercit. Anat. 1. sect. 1. and 37.

(*e*) The motive parts, and motion of caterpillars, are useful, not only to their progression and conveyance from place to place; but also to their more certain, easy, and commodious gathering

any other way; or the parts ministering to it, particularly the spine (*g*), and the muscles co-operating with the spine, in such as have bone, and the annular, and other muscles, in such as have none, all incomparably made for those curious, and, I may say, geometrical windings and turnings, undulations, and all the various motions to be met with in the reptile kind.

of food: for having feet before and behind, they are not only enabled to go by a kind of steps made by their fore and hind parts; but also to climb up vegetables, and to reach from the boughs and stalks for food at a distance; for which services their feet are very nicely made both before and behind. Behind, they have broad palms for sticking to, and these beset almost round with small sharp nails, to hold and grasp what they are upon; before, their feet are sharp and hooked, to draw leaves, etc. to them, and to hold the fore-part of the body, whilst the hinder parts are brought up thereto. But nothing is more remarkable in these reptiles, than that these parts and motions are only temporary, and incomparably adapted only to their present nympha-state; whereas in their aurelia-state, they have neither feet nor motion, only a little in their hinder-parts: and in the mature-state, they have the parts and motion of a flying insect made for flight.

(*f*) It is a wonderful pretty mechanism, observable in the going of multipedes, as the juli, scolopendrae, that on each side the body, every leg hath its motion, one very regularly following the other from one end of the body to the other, in a way not easy to be described in words; so that their legs in going, make a kind of undulation, and give the body a swifter progression than one would imagine it should have, where so many feet are to take so many short steps.

(*g*) 'Vertebrarum apophyses breviores sunt, praecipue junctura caput, cujus propterea flexus in aversum, et latera, facilis viperis est; secus leonibus, etc.—Incumbit his ossibus ingens musculorum minorum praesidium, tum spinas tendinum exitum magno apparatu deducendum, tum vertebrae potissimum in diversa flectentium, atque erigentium. Adeoque illam corporis miram agilitatem, non tantum, (ut Aristot.) ἐν εὐκαμπῶς ἔχει δρᾶσις οἱ σπονδυλοὶ, quoniam faciles ad flexum, et cartilagineas praeduxit vertebrae, sed quia etiam multiplicia motus localis instrumenta musculos fabrefecit provida rerum parens natura, composita fuit' Blas. Anat. Anim. p. 1. c. 39. de Vipera e Vestigia. That which is more remarkable in the vertebrae [of the rattlesnake, besides the other curious articulations], is, that the round ball in the lower part of the upper vertebra, enters the socket of the upper-part of the lower vertebra, like as the ball

Another thing that will deserve our notice, is, the poison (*b*) that many of this tribe are stocked with. Which I the rather mention, because some make it an objection against the divine superintendence and providence, as being a thing so far from useful, they think, that it is rather mischievous and destructive of God's creatures. But the answer is easy, viz. that as to man, those creatures are not without their great uses, particularly in the cure of some (*i*) of the most

of the os femoris doth the acetabulum of the os ischii; by which contrivance, as also the articulation with one another, they have that free motion of winding their bodies any way.' Dr Tyson's Anat. of the rattle-snake in Philosoph. Trans. No. 144. What is here observed of the vertebrae of this snake, is common to this whole genus of reptiles.

(*b*) My ingenious and learned friend, Dr Mead, examined with his microscope, the texture of a viper's poison, and found therein at first only 'a parcel of small salts nimbly floating in the liquor; but in a short time the appearance was changed, and these saline particles were shot out into crystals, of an incredible tenuity and sharpness, with something like knots here and there, from which they seemed to proceed; so that the whole texture did in a manner represent a spider's web, though infinitely finer.' Mead of Poisons, p. 9.

As to the nature and operation of this poison, see the same ingenious author's hypothesis, in his following pages.

This poison of the viper lieth in a bag in the gums, at the upper end of the teeth. It is separated from the blood by a conglomerated gland, lying in the anterior lateral part of the os maxillaris, just behind the orbit of the eye: from which gland lieth a duct, that conveys the poison to the bags at the teeth.

The teeth are tubulated, for the conveyance, or emission of the poison into the wound the teeth make; but their hollowness doth not reach to the apex, or top of the tooth, (that being solid and sharp, the better to pierce); but it ends in a long slit below the point, out of which the poison is emitted. These perforations of the teeth, Galen saith, the mountebanks used to stop with some kind of paste, before they suffered the vipers to bite them before their spectators. Cuts of these parts, etc. may be seen in the last cited book of Dr Mead. Also Dr Tyson's Anat. of the Rattle-Snake, in Phil. Trans. No. 144.

(*i*) That vipers have their great uses in physic, is manifest from their bearing a great share in some of our best antidotes, such as theriaca Andromachi, and others; also in the cure of the elephantiasis, and other the like stubborn maladies, for which I shall refer to the medical writers. But there is so singular a case in the curious collection of Dr Ol. Wormius, related from Kircher,

stubborn diseases; however, if they were not, there would be no injustice for God to make a set of such noxious creatures, as rods and scourges, to execute the divine chastisements upon ungrateful and sinful men. And I am apt to think that the nations which know not God, are the most annoyed with those noxious reptiles, and other pernicious creatures. As to the animals themselves, their poison is, no doubt, of some great and special use to themselves, serving to the more easy conquest, and sure capture of their prey, which might otherwise be too resty and strong, and if once escaped, would hardly be again recovered, by reason of their swifter motion, and the help of their legs; besides all which, this their poison may

that I shall entertain the reader with it. Near the village of Sassa, about eight miles from the city Bracciano in Italy, saith he, *Specus seu caverna, vulgo La Grotta del Serpi, duorum hominum capax, fistulosis quibusdam foraminibus in formam cribri perforata cernitur, ex quibus ingens quaedam, principio veris, diversiculorum serpentum, nulla tamen, ut dicitur, singulari veneni qualitate imbutorum progenies quotannis pullulare solet. In hac spelunca elephantiacos, leprosos, paralyticos, arthriticos, podagricos, etc. nudos exponere solent, qui mox halituum subterraneorum calore insudorem resoluti, serpentum propullulantium, totum corpus insu mi implicantium, suctu linstuque ita omni vitioso virulentoque humore privare dicuntur, ut repetito hoc per aliquod tempus medicamento, tandem perfectae sanitati restituantur.* This cave Kircher visited himself, found it warm, and every way agreeable to the description he had of it; he saw their holes, heard a murmuring hissing noise in them; but although he missed seeing the serpents, it being not the season of their creeping out, yet he saw great numbers of their exuviae, or sloughs, and an elm growing hard by laden with them.

The discovery of this cave was by the cure of a leper going from Rome to some baths near this place; who losing his way, and being benighted, happened upon this cave; and finding it very warm, pulled off his clothes, and being weary and sleepy, had the good fortune not to feel the serpents about him till they had wrought his cure. Vide Muscum Worm. l. 3. c. 9.

The before commended Dr Mead thinks our physicians deal too cautiously and sparingly, in their prescribing only small quantities of viper's flesh, etc. in the elephantiasis, and stubborn leprosy: but he recommended rather the gelly or broth of vipers; or as the ancient manner was, to boil vipers and eat them like fish; or at least to drink wine, in which they have been long infused. Vide Mead, ubi supra, p. 34.

probably be of very great use to the digestion of their food.

And as to the innocuous part of the reptile-kind, they as well deserve our notice for their harmlessness, as the others did for their poison. For as those are endowed with poison, because they are predacious; so these need it not, because their food is near at hand, and may be obtained without strife and contest, the next earth (*k*) affording food to such as can terebrate, and make way into it by their vermicular faculty; and the next vegetable being food to others that can climb and reach (*l*), or but crawl to it.

CHAP. II.

Of the INHABITANTS of the WATERS.

I HAVE now gone through that part of the animal world, which I proposed to survey, the animals inhabiting the land.

As to the other part of the terraqueous globe, the waters, and the inhabitants thereof, not having time to finish what I have begun on that large subject, I shall be forced to quit it for the present, although we have there as ample and glorious a scene of the infinite Creator's power and art, as hath been already set forth on the dry land. For the waters themselves

(*k*) That earth-worms live upon earth, is manifest from the little curled heaps of their dung ejected out of their holes. But in Phil. Trans. No. 291. I have said, it is in all probability earth made of rotted roots and plants, and such like nutritive things, not pure earth. And there is farther reason for it, because worms will drag the leaves of trees into their holes.

(*l*) Snails might be in danger of wanting food, if they were to live only upon such tender plants as are near the ground, within their reach only; to impower them therefore to extend their pursuits farther, they are enabled, by the means mentioned in note (*d*), p. 373. to stick unto, and creep up walls and vegetables at their pleasure.

are an admirable work of God (*a*), and of infinite use (*b*) to that part of the globe already surveyed; and the prodigious variety (*c*), and multitudes of curious and wonderful things observable in its inhabitants of all sorts, are an inexhaustible scene of the Creator's wisdom and power. The vast bulk of some (*d*), and prodigious minuteness of others (*e*), together with the incomparable contrivance and structure of the bodies of all (*f*); the provisions and sup-

(*a*) Besides their absolute necessity and great use to the world, there are several topics, from whence the waters may be demonstrated to be God's work; as the creating so vast a part of our globe; the placing it commodiously therein, and giving it bounds; the methods of keeping it sweet and clean, by its saltness, by the tides and agitations by the winds; the making the waters useful to the vegetation of plants, and for food to animals, by the noble methods of sweetening them; and many others things besides, which are insisted on in that part of my survey.

(*b*) Pliny having named divers *mirabilia aquarum*, to shew their power; then proceeds to their uses, viz. 'Eaedem cades tes omnium terra nacentium causa fiunt, prorsus mirabili natura, si quis velit reputare, ut fruges gignantur, arbores fruticesque vivant, in coelum migrare aquas, animamque etiam herbis vitalem inde deferre, iusta confessione, omnes terrae quoque vires aquarum esse beneficii. Quapropter ante omnia ipsarum potentiae exempla ponemus: cunctas enim quis mortalium enumerare queat?' And then he goes on with an enumeration of some waters famed for being medicinal, or some other unusual quality. Plin. l. 31. c. 1, and 2.

(*c*) Pliny reckons 176 kinds in the waters, whose names may be met with in his l. 32. c. 11. but he is short in his account.

(*d*) Pliny, l. 9. c. 3. saith, that in the Indian sea there are 'belenae quaternum iugerum, (i. e. 960 feet) pristis 200 cubitorum, (i. e. 300 feet.)' And l. 32. c. 1. he mentions whales 600 fathoms long, and 360 broad, that came into a river of Arabia. If the reader hath a mind, he may see his reason why the largest animals are bred in the sea, l. 9. c. 2.

(*e*) As the largest, so the most minute animals are bred in the waters, as those in pepper-water; and such as make the green scum on the waters, or make them seem as if green, and many others. See book iv. chap. 11. note (*n*), p. 196. and note (*q*) p. 197.

(*f*) It might be here shewn, that the bodies of all the several inhabitants of the waters, are the best contrived and suited to that place and business in the waters, which is proper for them; that particularly their bodies are clothed and guarded, in the best manner

plies of food afforded to such an innumerable company of eaters, and that in an element, unlikely, one would think, to afford any great store of supplies (*g*); the business of respiration performed in a way so different from, but equivalent to what is in land-animals (*h*); the adjustment of the organs of vision (*i*), to that element in which the animal liveth; the poise (*k*),

ner, with scales, or shells, etc. suitable to the place they are to reside in, the dangers they may be there exposed unto, and the motion and business they are there to perform: that the centre of gravity, of great consideration in that fluid element, is always placed in the fittest part of the body: that the shape of their bodies, especially the more swift, is the most commodious for making way through the waters, and most agreeable to geometrical rules; and many other matters besides would deserve a place here, were they not too long for notes, and that I shall anticipate what shall be more proper for another place, and more accurately treated of there.

(*g*) See before, book iv. chap. 11.

(*h*) Galen was aware of the respiration of fishes by their branchiae. For having said, that fishes have no occasion of a voice, neither respire through the mouth, as land-animals do, he saith, 'Sed earum, quas branchias nuncupamus, constructio, ipsis vice pulmonis est. Cum enim crebris ac tenuibus foraminibus sint branchiae hae interceptae, aeri quidem et vaporis perviis, subtilioribus tamen quam pro mole aquae; hanc quidem extra repellunt, illa autem prompte intromittunt.' Galen. de usu Part. l. 6. c. 9. So also Pliny held, that fishes respired by their gills, but he saith Aristotle was of a different opinion. Plin. l. 9. c. 7. and so Aristotle seems to be in his history of animals, l. 8. c. 2. and in other places. And I may add our famous Dr Needham. See his *De Form. Foet.* cap. 6. and Answer to Severinus.

(*i*) A protuberant eye would have been inconvenient for fishes, by hindering their motion in so dense a medium as water is; or else their brushing through so thick a medium would have been apt to wear, and prejudice their eyes; therefore their cornea is flat. To make amends for which, as also for the refraction of water, different from that of the air, the wise Contriver of the eye hath made the chrystalline spherical in fishes, which in animals, living in the air, is lenticular, and more flat.

(*k*) As I have shewed before, that the bodies of birds are nicely poised to swim in the air, so are those of fishes for the water, every part of the body being duly balanced, and the centre of gravity, as I said in note (*f*), p. 378. accurately fixed. And to prevent vacillation, some of the fins serve, particularly those of the belly; as Borelli proved, by cutting off the belly-fins, which

the support (*l*), the motion of the body (*m*), forwards with great swiftness, and upwards and downwards with great readiness and agility, and all without feet and hands, and ten thousand things besides; all these things, I say, do lay before us so various, so glorious, and withal so inexhaustible a scene of the divine power, wisdom, and goodness, that it would be in vain to engage myself in so large a province, without allotting as much time and pains to it, as the preceding survey hath cost me. Passing by therefore that part of our globe, I shall only say somewhat very briefly concerning the insensitive creatures, particularly those of the vegetable kingdom, and so conclude this survey.

B O O K X.

Of VEGETABLES.

THE vegetable kingdom, although an inferior branch of the creation, exhibits to us such an ample scene of the Creator's contrivance, curiosity, and art, that I much rather chuse to shew what might be said, than engage too far in par-

cause the fish to reel to the right and left hand, and rendered it unable to stand steadily in an upright posture.

(*l*) To enable the fish to abide at the top, or bottom, or any other part of the waters, the air-bladder is given to most fishes, which, as it is more full or empty, makes the body more or less buoyant.

(*m*) The tail is the grand instrument of the motion of the body; not the fins, as some imagine. For which reason, fishes are more musculous and strong in that part, than in all the rest of their body, according as it is in the motive parts of all animals, in the pectoral muscles of birds, the thighs of man, etc.

If the reader hath a mind to see the admirable method, how fishes row themselves by their tail, and other curiosities relating to their swimming; I shall refer him to Borelli de Mot. Animal. par. 1. cap. 23. particularly to prop. 213.

particulars. I might insist upon the great variety there is, both of trees and plants provided for all ages, and for every use and occasion of the world (*a*); some for building, for tools and utensils of every kind; some hard, some soft; some tough and strong, some brittle; some long and tall, some short and low; some thick and large, some small and slender; some for physic (*b*), some for food, some for pleasure; yea, the most abject shrubs (*c*), and the very bushes and

(*a*) The fifth book of Theophrastus's History of plants may be here consulted; where he gives ample instances of the various constitutions and uses of trees, in various works, etc. See also before, book iv. chap. 13. note (*a*), p. 232.

(*b*) 'Invisis quoque herbis inseruit [natura] remedia: quippe cum medicinas dederit etiam aculeatis—in quibus ipsis providentiam naturae satis admirari amplectique non est.—Inde excogitavit aliquas aspectu hispidas, tactu truces, ut tantum non vocem ipsius fingentis illas, rationemque reddentis exaudire videamur, ne se depascat avida quadrupes, ne proeaces manus rapiant, ne neglecta vestigia obterant, ne insidens ales infringat: his muniendo aculeis, telisque armando, remediis ut tuta ac salva sint. Ita hoc quoque quod in iis odimus, hominum causa excogitatum.' Plin. Nat. Hist. l. 22. c. 6.

'Are some of the species of nature noxious? They are also useful.—Doth a nettle sting? It is to secure so good a medicine from the rapes of children and cattle. Doth the bramble cumber a garden? It makes the better hedge; where if it chanceth to prick the owner, it will tear the thief.' Grew's Cosmolog. lib. 3. cap. 2. sect. 47.

(*c*) That the most abject vegetables, etc. have their use, and are beneficial to the world, may, in some measure, appear from the use the northern people put rotten wood, etc. unto. 'Satis ingeniosum modum habent populi septentrionales in nemoribus nocturno tempore pertranscuentes, imo et diurno, quando in remotioribus aquilonis partibus ante et post solstitium hyemale continuas noctes habentur. Quique his remediis indigent, cortices quercimos inquirunt putres, eosque collocant certo itinere itineris instituti, ut eorum splendore, quo vulnerint, perficiant iter. Nec solum hoc praestat cortex, sed et truncus putresfactus, ac fungus ipse agaricus appellatus,' etc. Ol. Mag. Hist. l. 2. c. 16.

To this we may add thistles in making glass, whose ashes, Dr Ferret saith, are the best, viz the ashes of the common-way thistle, though all thistles serve to this purpose. Next to thistles are hop-strings, cut after the flowers are gathered. Plants that are thorny and prickly, seem to afford the best and most salt. Ferret's Observations on Anton. Ner. p. 265.

brambles themselves, the husbandman can testify the use of.

I might also survey here the curious anatomy and structure of their bodies (*d*), and shew the admirable provision made for the conveyance of the lymphatic and essential juices, for communicating the air, as necessary to vegetable, as animal life (*e*): I might

Quid majora sequar? Salices, humilesque genistae,
Aut illae pecori frondem, aut pastoribus umbram
Sufficiunt, sepemque satis, et pabula melli.

Virg. Georg. l. 2. ver. 434.

(*d*) Dr Beal, who was very curious, and tried many experiments upon vegetables, gives some good reasons to imagine, that there is a direct communication between the parts of the tree and the fruit, so that the same fibres which constitute the root, trunk, and boughs, are extended into the very fruit. And in old horn-beans, I have observed something very like this: in many of which, there are divers great and small ribs, almost like ivy, only united to the body, running from the root up along the outside of the body, and terminating in one single, or a few boughs: which bough or boughs spread again into branches, leaves, and fruit. See what Dr Beal hath in Lowth. Abridgm. vol. 2. p. 710.

But as to the particular canals, and other parts relating to the anatomy of vegetables, it is too long a subject for this place, and therefore I shall refer to Seign. Malpighi's and Dr Grew's labours in this kind.

(*e*) 'Tanta est respirationis necessitas, et usus, ut natura in singulis viventium ordinibus varia, sed analoga, paraverit instrumenta, quae pulmones vocamus' [and so he goes on with observing the apparatus made in the various genera of animals, and then saith], 'In plantis vero, quae infimum animalium attingunt ordinem, tantam trachearum copiam et productionem extare par est, ut his minimae vegetantium partes praeter corticem irrigentur—Plantae igitur, ut conjectari fas est, cum sint vivientia, visceribus infixae terrae, ab hac, seu potius ab aqua et aere, commixtis et percolatis a terra, respirationis suae materiam recipiunt, ipsarumque tracheae ab halitu terrae, extrinsecus radices subingresso, replentur.' Malpig. Op. Anat. Plant. p. 15.

These tracheae, or air-vessels, are visible, and appear very pretty in the leaf of scabious, or the vine, by pulling asunder some of its principal ribs, or great fibres; between which, may be seen the spiral air-vessels, like threads of cobweb a little uncoiled; a figure whereof, Dr Grew hath given us in his Anat. Plant. Fig. 51, 52.

As to the curious coiling, and other things relating to the structure of those air-vessels, I refer to Malpighi, p. 14. and Dr

also speak of, even the very covering they are provided with, because it is a curious work in reality, although less so in appearance; and much more therefore might I survey the neat variety and texture of their leaves (*f*), the admirable finery, gaiety, and fragrantcy of their flowers (*g*). I might also inquire

Grew, *ib.* l. 3. c. 3. sect. 16. etc. and l. 4. c. 4. sect. 19. of Mr Ray, from them succinctly. *Hist. Plant.* l. 1. c. 4.

(*f*) Concerning the leaves, I shall note only two or three things: 1. As to the fibres of the leaf, they stand not in the stalk, in an even line, but always in an angular, or circular posture, and their vascular fibres or threads are 3, 5, or 7. The reason of their position thus, is for the more erect growth and greater strength of the leaf, as also for the security of its sap. Of all which, see Dr Grew, l. 1. c. 4. sect. 8. etc. and l. 4. par. 1. c. 3. also tab. 4. fig. 2, to 11. Another observable in the fibres of the leaf, is their orderly position, so as to take in an eighth part of a circle, as in mallows; in some a tenth, but in most a twelfth, as in holy-oak; or a sixth, as in syringa. *Id.* *ib.* tab. 46, 47.

2. The art in folding up the leaves before their eruption of their gems, etc. is incomparable, both for its elegance and security, viz. 'In taking up, so as their forms will bear, the least room; and in being so conveniently couched as to be capable of receiving protection from other parts, or of giving it to one another, e. g. first, there is the bow-lap, where the leaves are all laid somewhat convexly one over another, but not plaited —but where the leaves are not so thick set, as to stand in the bow-lap, there we have the plicature, or the flat-lap; as in 'rose trees,' etc. And so that curious observer goes on shewing the various foldings, to which he gives the names of the duplicature, multiplicature, the fore-rowl, back-rowl, and tre-rowl, or treble-rowl, Grew. *ib.* l. 1. c. 4. sect. 14. etc. To these he adds some others, l. 4. p. 1. c. 1. sect. 9. Consult also Malpig. de Gemmis, p. 22, etc.

To these curious foldings, we may add another noble guard by the interposition of films, etc. of which Dr Grew saith, there are about six ways, viz. leaves, surfoils, interfoils, stalk, hoods, and mantlings. Grew, *ib.* and tab. 41, 42. Malpig. *ib.*

(*g*) In the flower may be considered the empalement, as Dr Grew, the calix, or perianthium, as Mr Ray and others, call it, designed to be a security, and bands to the other parts of the flower. 'Florid velut basis et fulcimentum est.' Ray *Hist.* l. 1. c. 10. Flowers, whose petala are strong, as tulips, have no calix. Carnations, whose petala are long and slender, have an empalement of one piece: and others, such as the knap-weeds, have it consisting of several pieces, and in divers rounds, and all with a counter-changeable respect to each other, for the greater

into the wonderful generation and make of the seed (*b*), and the great usefulness of their fruit: I might shew that the rudiments and lineaments of the parent-vegetable, though never so large and spacious, is locked up in the little compass of their fruit or seed, though some of these seeds are scarce visible to the naked eye (*i*). And forasmuch as the perpetui-

strength and security of themselves, and the petala, etc. they include.

The next is the foliation, as Dr Grew, the petala, or folia, as Mr Ray, and others. In these not only the admirable beauty, and luxuriant colours are observable, but also their curious foldings in the calix, before their expansion. Of which Dr Grew hath these varieties, viz. the close-couch, as in roses; the concave-couch, as in *blattaria flore albo*; the single-plait, as in pease blossoms; the double-plait, as in blue-bottles, etc.; the couch and plait together, as in marigolds, etc.; the rowl, as in ladies-bower; the spire, as in mallows; and lastly, the plait and spire together, as in *convolvulus doronici folio*. Lib. 1. cap. 5. sect. 6. and tab. 54.

As to the stamina with their apices, and the stylus, called the attire, by Dr Grew, they are admirable, whether we consider their colours, or make, especially their use, if it be as Dr Grew, Mr Ray, and others imagine, namely, as a male sperm, to impregnate and fructify the seed. Which opinion is corroborated by the ingenious observations of Mr Samuel Morland, in Phil. Trans. No. 287.

‘Reliqua usus alimentique gratia genuit [natura] ideoque secula annosque tribuit iis. Flores vero odoresque in diem gignit: magna, ut palam est, admonitione hominum, quae speculatissime floreat, celerrime marcescere.’ Plin. Nat. Hist. l. 21. c. 1.

(*b*) As to the curious and gradual process of nature in the formation of the seed or fruit of vegetables, cuts being necessary, I shall refer to Dr Grew, p. 45. and 209. and Malpig. p. 57.

(*i*) ‘Vetus est Empedoclis dogma, plantarum semina ova esse, ab iisdem decidua—Inest in eo [ovo vel semine] velut in cicatrice, non sola viventis carina, sed cum minimo trunco assertur gentes partes, gemma scilicet, et insignis radicis canas,’ etc. Malp. ib. p. 81. Vide plura in tract. de Sem. veg. p. 14. et passim.

In Malpighi’s life, a debate may be seen between him and Seig. Triumphetti, the provost of the garden at Rome, whether the whole plant be actually in the seed. The affirmative is maintained by Malpighi, with cogent arguments; among which, this is one: ‘Non praeoccupata mente, oculis microscopio armatis, lustrat quae so phaeolorum seminalem plantulam nondum satam

ty and safety of the species depends upon the safety of the seed and fruit in a great measure, I might there-

‘in qua folia stabilia, haecque ampla evidenter observabit; in eadem pariter gemmam, nodos, seu implantationes varias foliorum caulis deprehendet. Caulem insignem fibris ligneis, et utriusque colorum seriebus constantem conspicue attinget.’ And whereas Seig. Triumphetti had objected, that ‘Vegetatione, metamorphosi, inedia plantas in alias degenerare, ut exemplo plurimum [constat] praecipue tritici in lolium, et lolii in triticum versi.’ In answer to this, which is one of the strongest arguments against Malpighi’s assertion, Malpighi replies, ‘Nondum certum est de integritate, et successu experimenti, nam facienti mihi, et amicis, tritici metamorphosis non cessit. Admissa tamen metamorphosi, quoniam haec neglecta cultura, aut vitio soli, aut aeris contingit—ideo ex morbo et monstruoso affectu non licet inferre permanentem statum a natura intentum. Observo plantas sylvestres cultura varias reddi.’ etc. I have more largely taken notice of Malpighi’s answer, because he herein shews his opinion about the transmutation of vegetables. Vide Malpig. Vit. p. 67.

So Mr Lewenhoeck, after his nice observations of an orange-kernel, which he made to germinate in his pocket, etc. concludes, ‘Thus we see, how small a particle, no bigger than a coarse sand, (as the plant is represented), is increased, etc. A plain demonstration, that the plant, and all belonging to it, was actually in the seed, in the young plant, its body, root,’ etc. Philos. Trans. No. 287. See also Raii Cat. Cant. in Acer maj. from Dr Highmore. But in all the seeds which I have viewed, except the maple, the plant appears the plainest to the naked eye, and also very elegant, in the aux vomica.

‘Natura non observat magnitudinis proportionem inter semina et plantas ab iisdem ortas, ita ut majus semen majorem semper producat plantam, minus minorem. Sunt enim in genere herbarum non pauca, quarum semina arborum nonnullarum seminibus non dico aequalia sunt, sed multo majora. Sic. v. g. semina fabae, etc. semina ulmi, etc. multis vicibus magnitudine superant.’ Raii, ubi supra, l. 1. c. 13.

‘Filicem reliquasque capillares herbas semine carere veteres plerique—prodidere; quos etiam secuti sunt e recentioribus nonnulli, Dodonaeus, etc.—Alii e contra, Bauhinus, etc. Filices et congenere spermatophoras esse contendunt; partim quia historia creationis.’ Gen. ii. 12. etc.—hanc sententiam verissimam esse—autopsia convincit.’ Fredericus Caesius, he saith, was the first that discovered these seeds with the help of a microscope. And since him, Mr W. C. hath more critically observed them. Among other things observed by that ingenious gentleman, are these, ‘Pixidulae seu capsulae semina continentes in plerisque hoc genus plantis perquam exili granulo arenae vulgaris cinereae plus duplo minores sunt; imo in nonnullis spe-

fore take notice of the peculiar care the great God of nature hath taken for the conservation and safety hereof: as particularly in such as dare to shew their heads all the year, how securely their flower, seed, or fruit is locked up all the winter, together with their leaves and branches, in their gems (*k*), and well fenced and covered there with neat and close tunics. And for such as dare not so to expose themselves, with what safety they are preserved under the coverture of the earth, in their root (*l*), seed (*m*), or fruit, till invi-

* ciebus vix tertiam quartamve arenulae partem magnitudine aequant, vesicularum quarundam annulis aut fasciis vermiciformibus obvolutarum speciem exhibentes. Nonnullae ex his vesicularis 100 circiter semina continere deprehendebantur—adeo eximia parvitate ut nudo oculo prorsus essent invisibilia, nec nisi microscopii interventu detegi possent.—*Osmunda regalis*, quae aliis omnibus filicis speciebus mole—antecellit—vasculum seminalis obtinet aequae cum reliquis congeneribus magnitudinis—quorum immensa et visum fugiens parvitas cum magnitudine plantae collata—adeo nullam gerere proportionem invenietur, ut tantam plantam e tantillo semine produci attentum observatore merito in admirationem rapiat.' Ray, *ibid.* l. 3. p. 132. This W. C. was Mr Will. Cole, as he owneth in a letter I have now in my hands of his to Mr Ray, Oct. 18. 1684.

(*k*) 'Vegetantium genus, ut debitam magnitudinem sortiatur, et suae mortalitatis jacturam successiva prolis educatione reparat, statim temporibus novas promittit partes, ut tandem emergentes uteri, recentes edant soboles. Emanantes igitur a caule, caudice, ramis, et radicibus novellae hujusmodi partes, non illico laxatae extenduntur, sed compendio quodam coagmentatae intra folii axillam cubantes, non parum subsistunt, gemmae appellantur,' etc. And then that great man goes on to shew the admirable various methods of nature, in repositing, in that little compass, so large a part of a tree or plant, the curious structure of the gems, the admirable guard afforded them, and the leaves, flowers and seed contained in them, etc. Of which having taken notice before, I pass over it now, and only refer to our author Malpighi, and Dr Grew, in the places cited in note (*e*), 382. and note (*g*), p. 383.

(*l*) Of bulbous, and a great many more, probably of the far greater number of perennial roots of herbs, as arum, rape-crow-foot, etc. it is very observable, that their root is annually renewed, or repaired out of the trunk or stalk of itself; that is to say, the basis of the stalk continually and by insensible degrees descending below the surface of the earth, and hiding itself therein, is thus both in nature, place, and office, changed into a true

ted out by the kindly warmth of the spring ! And when the whole vegetable race is thus called out, it is very pretty to observe the methods of nature in guarding those insensitive creatures against harms and inconveniencies, by making some, for instance, to lie down prostrate, and others, to close themselves up (*n*) upon the touch of animals, and the most to shut up their flowers, their down (*o*), or other their

root—So in brown-wort, the basis of the stalk sinking down by degrees, till it lies under ground, becomes the upper part of the root : and continuing still to sink, the next year becomes the lower part : and the next after that, rots away ; a new edition being still yearly made out of the stalk, as the elder parts yearly rot away. Grew, ib. l. 2. p. 59. ubi plura vid.

(*m*) How safe and agreeable a conservatory the earth is to vegetables, more than any other, is manifest from their rotting, drying, or being rendered infecund in the waters. or the air ; but in the earth, their vigour is long preserved. Thus of seeds particularly, Mr Ray thinks, some may probably retain their fecundity for ten years, and others lose it in five ; but, saith he, ‘ In terrae gremio latitantia, quamvis tot caloris, frigoris, humoris et siccitatis varietatibus ibidem obnoxia, diutius tamen, ut puto, fertilitatem suam tuentur quam ab hominibus diligentissime custodita ; nam et ego et alii ante me multi observant sinapeos vim magnam enatam in aggeribus fossarum recens factis inque areis gramineis effosis, ubi post hominum memoriam nulla unquam sinapeos seges succreverat. Quam tamen non sponte ortam suspicor, sed e seminibus in terra per tot annos residuis etiam prolificis.’ Ray, Hist. Pl. l. 1. c. 13.

(*n*) ‘ Plantae nonnullae aesclynomenae veteribus dictae, recentioribus vivae, et sensitivae, et mimosae, haud obscura sensus indicia produnt ; siquidem folia earum manu aut baculo tacta, et paululum compressa, pleno etiam meridie, splendente sole, illico se contrahunt ; in nonnullis etiam speciebus cauliculi teneriores concidunt et velut marcescunt ; quod idem ab aere frigidiore admissio patiuntur.’ Ray, Hist. Pl. T. 1. l. 18. Appendix. 2. c. 2. p. 978.

(*o*) I have observed that many, if not most vegetables, do expand their flowers, down, etc. in warm, sun-shiny weather, and again close them towards evening, or in rain, etc. especially at the beginning of flowering, when the seed is young and tender ; as is manifest in the down of dandelion, and other downs ; and eminently in the flowers of pin-pernel ; the opening and shutting of which, are the countryman’s weather-wiser ; where-by Gerard saith, he foretellet what weather shall follow the next day ; for, saith he, ‘ If the flowers be close shut up, it betoken-

like guard, upon the close and cool of the evening, by means of rain, or other matters that may be prejudicial to the tender feed.

And now to these considerations relating to the seed, I might add the various ways of nature in dissipating and sowing it, some being, for this end, winged with light down, or wings, to be conveyed about by the winds; others being laid in elastic, springy cases, that when they burst and crack, dart their seed at convenient distances, performing thereby the part of a good husbandman (*p*); others by

‘eth rain and foul weather; contrariwise, if they be spread a broad, fair weather,’ Ger. Herb. b. 2. c. 183.

‘Est et alia [arbor in Tylis] similis, foliosior tamen, roseique floris; quem noctu comprimens, aperire incipit solis exortu, meridie expandit. Incolae dormire eam dicunt.’ Plin. Nat. Hist. l. 12. c. 11.

(*p*) ‘So soon as the seed is ripe, nature taketh several methods for its being duly sown; not only in the opening of the uterus, but also in the make of the seed itself. For, first, the seeds of many plants, which affect a peculiar soil or seat, as of arum, poppy, etc. are heavy and small enough, without farther care, to fall directly down into the ground.——But if they are so large and light, as to be exposed to the wind, they are often furnished with one or more hooks, to stay them from straying too far from their proper place.——So the seeds of avens have one single hook; those of agrimony and goose-grass, many; both the former loving a warm bank; the latter, an hedge for its support. On the contrary, many seeds are furnished with wings or feathers; partly with the help of the wind to carry them, when ripe, from off the plant, as of alh, etc.—and partly to enable them to make their flight more or less abroad, that so they may not, by falling together, come up too thick; and that if one should miss a good soil or bed, another may hit. So the kernels of pine have wings—yet short—whereby they fly not into the air, but only flutter upon the ground. But those of typha, dandelion, and most of the papous kind——have long numerous feathers, by which they are wafted every way.—Again, there are seeds which are scattered not by flying abroad, but by being either spirted or slung away. The first of these are wood-correl, which having a running root, nature sees fit to sow the seeds at some distance. The doing of which is effected by a white sturdy cover, of a tendinous or springy nature.—This cover, so soon as it begins to dry, bursts open on one side, in an instant, and is violently turned inside outward—and so smartly throws off the seed.

their agreeable taste and smell, and salutary nature, inviting themselves to be swallowed and carried about

‘The seed of harts-tongue is slung or shot away—by the curious contrivance of the seed-case, as in coddled arsmart, only there the spring moves and curls inward, but here outward; viz. every seed-case—is of a spheric figure, and girded about with a sturdy spring.—The surface of the spring resembles a fine screw.—So soon as this spring is become stark enough, it suddenly breaks the case into two halves, like two little cups, and so slings the seed.’ Grew, *ib.* p. 199. and in *tab.* 72. all these admirable artifices are handsomely represented.

‘Quin si quantitas modica seminum [filicis phyllitidis quoque] a foliis in subjectam chartae mundae—schedam decuriatur, detergaturve, et deinde in acervum converratur, vesicularum seminalium plurimis una dissiliantibus, et sibi invicem allisis, acervulus varie moveri per partes videbitur, non secus ac si syrenibus aut istiusmodi bestiolis repletus esset—quin si locus tranquillus sit, aure proxime admota, crepitantium inter rumpendum vasculorum sonitus—percipietur; et si microscopio chartam oculis oberres, semina per eam undique sparsa, et ad notabilem ab acervo distantiam projecta comperies.’ Ray, *ibid.* p. 132.

‘The admirable contrivance of nature in this plant is most plain: for the seed-vessels being the best preserver of the seed, it is there kept from the injuries of air and earth, till it be rainy, when it is a proper time for it to grow, and then it is thrown round the earth, as grain by a skilful sower.—When any wet touches the end of the seed-vessels, with a smart noise and sudden leap it opens itself, and with a spring scatters its seed to a pretty distance round it, where it grows.’ Dr Sloane *Voy. to Jamaica*, p. 150. of the gentianella flore coeruleo, etc. or spirit-leaf.

The plants of the cardamime family, and many others, may be added here, whose coats fly open, and dart out their seed, upon a small touch of the hand. But the most remarkable instance is in the cardamime impatiens, ‘Cujus siliquae,’ saith Mr Ray, ‘vel leviter tactae, actutum ejaculantur [semina] imo quod longe mirabilius videtur, etsi siliquas non tetigeris, si tamen manum velut tacturus proxime admoveas, semina in appropinquantem evibrabunt; quod tum Morisonus se saepius expertum scribit, tum Johnstonus apud Gerardum verum esse affirmat.’ *Hist. Plant.* 16. c. 20.

Neither is this provision made only for land vegetables, but for such also as grow in the sea. Of which I shall give an instance from my before-commended friend, Dr Sloane; ‘As to the fuci,—their seed hath been discovered, and shewed me first, by the industry of the ingenious herbarist, Mr Sam. Doody, who found on many of this kind, solid tubercules, or risings. in some seasons, wherein were lodged several round seeds, as big

by the birds, and thereby also fertilized by passing through their bodies (*q*) ; and others not thus taken

‘ as mustard-seed, which, when ripe, the outward membrane of the tubercle breaking, leaveth the seed to float up and down with the waves. The seed coming near stones, or any solid foundation, by means of a mucilage it carries with it, sticks to them, and shoots forth ligulae with branches, and in time comes to its perfection and magnitude.’ Sloan. Voy. Jamaica, p. 50.

But although Mr Doody had hinted, and conjectured at the thing, yet the first that discovered the seeds in fuci was the before-commended Dr Tancred Robinson ; as may be seen by comparing what Mr Ray saith in his Synopf. Stirp. Brit. p. 6. with his Append. Hist. p. 1849. Besides which fuci, the Dr tells me, he observed vessels and seed in carolloid shrubs, as also in several fungi, not only in the species of crepitus lupi, but also between the lamellae of other species, and in that subterraneous kind called truffles, whose seed and vessels open in the cortex, at some seasons, he saith, like that of mallows in shape.

As to the crepitus lupi, I have more than once examined their powder, with those excellent microscopes of Mr Wilson’s make ; but the most satisfactory view Mr Wilson himself gave me ; by which I found the seeds to be so many exceeding small puff-balls, with round heads, and longer than ordinary sharp-pointed stalks, as if made on purpose to prick easily into the ground. These seeds are intermixed with much dusty matter, and become hurtful to the eyes, probably by their sharp stalks pricking and wounding that tender organ.

(*q*) The ancient naturalists do generally agree, that misseltoe is propagated by its seeds carried about by, and passing through the body of birds. Thus Theophrastus, de Caus. Plant. l. 2. c. 24. ‘ Τὸ δὲ ἀπὸ τῆς ορνιθῶν, etc. Initium vero a pastu avium :—quippe visco detracto confectoque in alveis, quod frigidissimum est, semen cum excremento purum dimittitur, et facta mutatione aliqua in arbore stercoris causa pullulat, erumpitque,’ etc. So also Pliny saith, viz. ‘ Omnino autem satum [viscum] nullo modo nascitur, nec nisi per alvum avium redditum, maxime palumbis ac turdi. Haec est natura, ut nisi maturatum in ventre avium, non proveniat.’ Plin. Nat. Hist. l. 16. c. 44. Whether what Theophrastus and Pliny affirm, be conducive to the better fertilizing the seeds of misseltoe, I know not ; but that it is not of absolute necessity, I can affirm upon mine own experience, having seen the seeds germinate, even in the bark of oak. But although they shot above an inch, and seemed to root in the tree, yet they came to nothing ; whether destroyed by ants, etc. which I suspected, or whether disagreeing with the oak, I know not. But I since find the matter put out of doubt by Mr Doody : which see in Mr Ray’s Hist. Plant. Appen. p. 1918.

Nutmegs are said to be fertilized after the same manner, at

care of, do many of them by their usefulness in human life, invite the husbandman and gardiner carefully to sow and nurse them up.

To this so singular a care about the propagation and conservation of the species of vegetables, I might add the nice provision that is made for their support and aid, in standing and growing, that they may keep their heads above ground, and not be rotted and spoiled in the earth themselves, nor thereby annoy us; but, on the contrary, minister to all their ends, and our uses; to afford us houses, utensils, food (*r*), physic, clothing, yea, diversion too, by

Tavernier saith was confirmed to him by persons that lived many years in those parts; whose relation was: the nutmeg being ripe, several birds come from the islands towards the south, and devour it whole, but are forced to throw it up again, before it be digested: and that the nutmeg, then besmeared with a viscous matter, falling to the ground, takes root, and produces a tree, which would never thrive, was it planted. Tavern. of the Commod. of the Gr. Mogul. And monsieur Thevenot, in his travels to the Indies, gives this account: The tree is produced after this manner; there is a kind of birds in the island, that having picked off the green husk, swallow the nuts, which, having been some time in their stomach, they void by the ordinary way; and they fail not to take rooting in the place where they fall, and in time grow up to a tree. This bird is shaped like a cuckow; and the Dutch prohibit their subjects, under pain of death, to kill any of them. Vide Sir T. Pope-Blunt's Nat. Hist.

But Mr Ray gives a somewhat different account: 'Hunc fructum [nucem Moschatam] variae quidem aves depascuntur, sed maxime columbae genus album et parum, quae dehiscente nucamento, illecebrae suavitatem macis, hunc cum nucem eripiunt et devorant, nec nisi repleta ingluvie capacissima saginam deserunt. Nostrates ibi mercatores columbis istis *nuc-eaters*, sive nucivoris nomen imposuerunt. Quas autem vorant nubes, post integras per alvum reddunt. Redditae citius deinde germinant utpote praemaceratae fervore ventriculi. Arborea inde natae ceu praecociiores, facile sunt corruptioni obnoxiae fructumque ferunt caeteris multo villiorem, et hac causa neglectum incolis continentumque, praeter macin, quem ad adulterandum meliorem adhibent.' Ray, Hist. Plant. l. 27. c. 4.

(*r*) 'Arbores blandioribus fruge succis hominem mitigavere. Ex iis recreans membra olei liquor, viresque potus vini; tot denique saporibus annui sponte venientes: et mensae, depugnetur licet earum causa cum feris, et pasti naufragorum corporibus pisces expetantur, etiamnum tamen secundae. Nulle praeterea

the beauty of their looks, by the fragrancy of their smell, by creating us pleasant shades against the scorching beams of summer, and skreening us against the piercing winds, and cold of winter (*f*).

And it is very observable, what admirable provisions are made for this purpose of their support and standing, both in such as stand by their own strength, and such as need the help of others. In such as stand by their own strength, it is by means of the stronger and more ligneous parts, equivalent to the bones in animals, being made not inflexible, as bones; because they would then be apt to break; but of a yielding elastic nature, to escape and dodge the violence of the winds, and by means also of the branches spreading handsomely and commodiously about, at an angle of about 45 gr. by which means they equally fill up, and at the same time make an aequilibration of the top (*s*).

‘sunt usus earum, sine quibus vita degi non possit. Arbore ful-
‘camus maria, terrasque admovemus, arbore exaedificamus tec-
‘ta.’ Plin. Nat. Hist. l. 12. c. 1.

(*f*) ‘Plantarum usus latissime patet, et in omni vitæ parte
‘occurrit. Sine illis laute, sine illis commode non vivitur, at
‘nec vivitur omnino: quaecunque ad victum necessaria sunt,
‘quaecunque ad delicias faciunt, e locupletissimo suo penu abun-
‘de subministrant. Quanto ex iis mensa innocentior, mundior,
‘salubrior quam ex animalium caede et laniena? Homo certe
‘natura animal carnivororum non est; nullis ad prædam et ra-
‘pinam armis instructum, non dentibus exertis et serratis, non
‘unguibus aduncis. Manus ad fructus colligendos, dentes ad
‘mandendos comparati. Non legimus ei ante diluvium carnes
‘ad esum concessas. At non victum tantum nobis suppeditant,
‘sed et vestitum, et medicinam, et domicilia, aliaque aedificia,
‘et navigia, et suppellectilem, et focum, et oblectamenta sen-
‘suum animique: ex his naribus odora et suffumigia paran-
‘tur. Horum flores inenarrabili colorum et schematum varie-
‘tate, et elegantia, oculos exhilarant, suavissima odorum quos
‘expirant fragrantia spiritus recreant. Horum fructus gulæ il-
‘lecebrae mensas secundas instruunt, et languentem appetitum ex-
‘citant. Taceo virorem amoenissimum oculis amicum, quem
‘per prata pascua agros, sylvas spatiantibus obijciunt, et umbras
‘quas contra aestum et solis ardores præbent.’ Ray, ib. l. 1.
c. 24. p. 46.

(*s*) All vegetables of a tall and spreading growth seem to have

And as for such vegetables as are weak, and not able to support themselves, it is a wonderful faculty they have, so readily and naturally to make use of the help of their neighbours, embracing and climbing up upon them (*t*), and using them as crutches

a natural tendency to a hemispherical dilatation, but generally confine their spreading within an angle of 90 gr. as being the most becoming and useful disposition of its parts and branches. Now, the shortest way to give a most graceful and useful filling to that space of dilating and spreading out, is to proceed in straight lines, and to dispose of those lines in a variety of parallels, etc. And to do that in a quadrantal space, etc. there appears but one way possible, and that is, to form all the intersections, which the shoots and branches make, with angles of 45 gr. only. And I dare appeal to all, if it be not in this manner, almost to a nicety observed by nature, etc. A visible argument that the plastic capacities of matter are governed and disposed by an all-wise and infinite Agent, the native strictnesses and regularities of them plainly shewing from whose hand they come. Account of the Origin and Formation of Fossils, Shells, etc. Printed at London, 1705. p. 38. 41.

(*t*) 'In Hedera, furculi et rami hinc inde claviculos, quasi radículas emittunt, quae parietibus, vel occurrentibus arboribus veluti digitis firmantur, et in altum suspenduntur. Hujusmodi radícula subrotundae sunt, et pilis cooperiuntur; et quod mirum est, glutinosum fundunt humorem, seu terebinthinam, qua arcte lapidibus nectuntur et agglutinantur.——Non minori industria natura utitur in vite Canadensi,' etc. The admirable and curious make of whose tendrils and their feet, see in the illustrious author, Malpig. de Capreolis, etc. p. 48

Claspers are of a compounded nature, between that of a root and a trunk. Their use is sometimes for support only; as in the claspers of vines, briony, etc. whose branches being long, slender, and fragile, would fall by their own weight, and that of their fruit; but these claspers take hold of any thing that is at hand; which they do by a natural circumvolution which they have; (those of briony have a retrograde motion about every third circle, in the form of a double clasp; so that if they miss one way, they may catch the other). Sometimes the use of claspers is also for a supply, as in the trunk-roots of ivy; which being a plant that mounts very high, and being of a closer and more compact substance than that of vines, the sap would not be sufficiently supplied to the upper sprouts, unless these assisted the mother-root; but these serve also for support too. Sometimes also they serve for stabiliment, propagation, and shade; for the first of these serve the claspers of cucumbers; for the second, those, or rather the trunk-roots of chamomil; and for all three, the trunk-roots of strawberries. Harris Lex Tech. in verb. Claspers.

to their feeble bodies: some by their odd convolving faculty, by twisting themselves like a screw about others; some advancing themselves by catching and holding with their curious clasps and tendrils, equivalent to the hands; some by striking in their rooty feet; and others by the emission of a natural glue, closely and firmly adhering to something or other that administers sufficient support unto them. All which various methods being so nicely accommodated to the indigencies of those helpless vegetables, and not to be met with in any besides, is a manifest indication of their being the contrivance and work of the Creator, and that his infinite wisdom and care condescends, even to the service, and well-being of the meanest, most weak, and helpless insensitive parts of the creation.

In the last place, to the uses already hinted at, I might add a large catalogue of such among vegetables, as are of peculiar use and service to the world, and seem to be designed, as it were, on purpose, by the most merciful Creator, for the good of man, or other creatures (*u*). Among grain, I might name the great fertility (*x*) of such as serves for bread, the easy culture and propagation thereof, and the agreement of every soil and climate to it. Among trees, and plants, I might instance in some that seem to be designed, as it were, on purpose, for almost every use (*y*), and convenience; some to heal the most

(*u*) Vegetables afford not only food to irrationals, but also physic, if it be true which Aristotle saith, and after him Pliny; which latter, in his 8th book, chap. 27. specifies divers plants made use of as specifics, by divers, both beasts and birds: as dittany by wounded deer; celandine by swallows, to cure the sore eyes of their young, etc. And if the reader hath a mind to see more instances of this nature, many of them fanciful enough, he may consult Merfenne in Genes. p. 933.

(*x*) See before, book iv. chap. 11. note (*b*), p. 192.

(*y*) ' *Planta haec unica [aloe Americana] inquit Fr. Hernandez, quicquid vitae esse potest necessarium praestare facile potest, si esset rebus humanis modus. Tota enim illa lignorum sepiendorumque agrorum usum praestat, caules tignorum, folia vero*

stubborn and dangerous distempers (z), to alleviate and ease the pains (aa) of our poor infirm bodies, all

‘testa tegendi imbricum, lancium: eorundem nervuli et fibrae eundem habent usum ad lintamina, calceos, et vestimenta conficienda quem apud nos linum, cannabis, gossipium, etc. E mucronibus fiunt clavi, aculei, subulae, quibus perforandis auribus, macerandi corporis gratia, Indis uti mos erat cum daemonum vacarent cultui; item aciculae, acus, tribuli militares et rastilla idonea pestendis subtegminibus. Praeterea e succo mananti, cujus evulsis germinibus internis foliisque tenerioribus cultus [Yztlinis] in mediam cavitatem, stillat planta, unica ad 50 interdum amphoras, quod dictu est mirabile, vina, mel, acetum, ac saccharum parantur. [The methods of which he tells]. Idem succus menses ciet, alvum lenit, urinam evocat, renes et vesicam emundat. E radice quoque restes fiunt firmissimae. Crassiores foliorum partes, truncusque, decocta sub terra, edendo sunt apta, sapiuntque citrea frusta saccharo condita: quin et vulnera recentia mire conglutinant.—Folia quoque assa et affecto loco imposita convulsionem curant, ac dolores leniunt, praecipue si succus ipse calens bibatur, quamvis ab Indica profisciscantur lue, sensum hebetant, atque torporem inducunt. Radicis succus lue Veneream curat apud Indos, ut Dr Palmer.’ Ray, ib. l. 2. c. 7. See also Dr Sloane’s Voyage to Jamaica, p. 247.

There are also two sorts of aloe besides, mentioned by the same Dr Sloane, one of which is made use of for fishing-lines, bow-strings, stockings, and hammocs. Another hath leaves that hold rain-water, to which travellers, etc. resort to quench their thirst, in scarcity of wells, or waters, in those dry countries. Ibid. p. 249.

(z) For instance here, I shall name the cortex Peruvianus, which Dr Morton calls ‘antidotus in levamen aerumnarum vitae humanae plurimarum divinitus concessa.’ De Febr. Exer. v. 3. ‘In sanitatem gentium, proculdubio a Deo O. M. conditus. Cujus gratia, arbor vitae, siqua alia, jure merito appellari potest.’ Id. ib. c. 7. ‘Eheu! quot convitiis Herculeae et divinae haec antidotes jactabatur!’ Ibid.

To this (if we may believe the Eph. Germ. An. 12. Obs. 74. and some other authors) we may add trifolium paludosum, which becomes the panacea of the German and northern nations.

(aa) ‘Pro doloribus quibuscunque sedandis praestantissimi semper usus opium habetur; quamobrem merito Nepenthe appellari solet, et remedium vere divinum existit. Et quidem satis mirari vix possumus, quomodo urgente visceris aut membri culpiam tortura insigni, et intolerabili cruciatu, pharmacum hoc, incantamenti instar, levamen et ἀναλγησίαν subitam, immo interdum absque somno, aut saltem prius quam advenerit, concedit. Porro adhuc magis stupendum est, quod donec particulae opiaticae operari, et potentiam suam narcoticam exercere

the world over: and some designed for the peculiar service and good of particular places, either to cure such distempers as are peculiar to them, by growing more plentifully there than elsewhere (*bb*), or else to obviate some inconvenience there, or to supply some constant necessity, or occasion, not possible, or at least not easy, to be supplied any other way (*cc*). It

‘continuant, immo etiam aliquamdiu postquam somnus finitur, summa alleviatio, et indolentia in parte affecta persistit.’ Willis, *Phar. Rat. Par.* 1. sect. 7. c. 1. sect. 15.

(*bb*) ‘Tales plantarum species in quacunque regione a Deo creantur quales hominibus et animalibus ibidem natis maxime conveniunt: imo ex plantarum nascentium frequentia se fere animadvertere posse quibus morbis [endemiis] quaelibet regio subjecta sit, scribit Solenander. Sic apud Danos, Frisios, Hollandos, quibus scorbutus frequens, cochlearia copiose provenit,’ Ray, *Hist. Plant.* l. 16. c. 3.

To this may be added, *Elfner's* observations concerning the virtues of divers things, in his *Observations de Vincetoxicæ Scrophularum remedio.* E. Germ. T. 1. obl. 57.

John Benorovinus, a physician of Dort, may be here consulted, who wrote a book on purpose to shew, that every country hath every thing serving to its occasions, and particularly remedies afforded to all the distempers it is subject unto. See *Benorovini Aurapexia Batav.* five *Introductio ad Medicinam indigenam.*

(*cc*) The description *Dr Sloane* gives of the wild-pine is, that its leaves are channeled, fit to catch and convey water down into their reservoirs; that these reservoirs are so made as to hold much water, and close at top when full, to hinder its evaporation; that these plants grow on the arms of the trees in the woods every where [in those parts], as also on the barks of their trunks. And one contrivance of nature in this vegetable he saith, is very admirable. The seed hath long and many threads of tomentum, not only that it may be carried every where by the wind,—but also, that it may by those threads, when driven through the boughs, be held fast, and stick to the arms, and exterior parts of the barks of trees. So soon as it sprouts or germinates, although it be on the under part of a bough,—its leaves and stalk rise perpendicular, or strait up, because if it had any other position, the cistern (before mentioned, by which it is chiefly nourished—) made of the hollow leaves, could not hold water, which is necessary for the nourishment and life of the plant.—In scarcity of water, this reservoir is necessary and sufficient, not only for the plant itself, but likewise is very useful to men, birds, and all sorts of insects, whither they come in troops, and seldom go away without refreshment. *Id.* ib. p. 180. and *Phil. Trans.* No. 251. where a figure is of this notable plant as also in *Lowthorp's Abridg.* vol. 2. p. 669.

is, for instance, an admirable provision made for some countries subject to drought, that when the waters every where fail, there are vegetables which contain not only moisture enough to supply their own vegetation and wants, but afford drink also both to man and other creatures, in their great extremities (*dd*); and a great deal more might be instanced in a like nature, and things that bear such plain impresses of the divine wisdom and care, that they manifest the superintendence of the infinite Creator.

Thus I have given a sketch of another branch of the creation, which, (although one of the meanest,

The wild pine so called, etc. hath leaves that will hold a pint and a half, or quart of rain-water; and this water refreshes the leaves, and nourishes the root. When we find these pines, we stick our knives into the leaves, just above the root, and that lets out the water, which we catch in our hats, as I have done many times to my great relief. Dampier's *Voy. to Campeachy*, c. 2. p. 56.

(*dd*) Navarette tells us of a tree called the bejuco, which twines about other trees, with its end hanging downwards; and that travellers cut the nib off it, and presently a spout of water runs out from it, as clear as crystal, enough, and to spare, for six or eight men. I drank, saith he, to my satisfaction of it, found it cool and sweet, and would drink it as oft as I found it in my way. It is a juice and natural water. It is the common relief of the herdsmen on the mountains; when they are thirsty they lay hold on the bejuco, and drink their fill. *Collect. of Voy. and Trav. vol. 1. in the Sup. to Navarette's Acc. of China*, p. 355.

The waterwith of Jamaica hath the same uses; concerning which, my before-commended friend, Dr Sloane, favoured me with this account from his original papers: 'This vine growing on dry hills in the woods, where no water is to be met with, its trunk, if cut into pieces two or three yards long, and held by either end to the mouth, affords so plentifully a limpid, innocent and refreshing water, or sap, as gives new life to the droughty traveller or hunter. Whence this is very much celebrated by all the inhabitants of these islands, as an immediate gift of providence to their distressed condition.'

To this we may add what Mr Ray takes notice of concerning the birch tree. 'In initiis veris antequam folia prodire, vulnerata dulcem succum copiose effundit, quem siti pressi pastoris in sylvis sæpenumero potare solent. Nos etiam non semel eo liquore recreati sumus. cum herbarum gratia vastas peragravimus sylvas, inquit Tragus.' *Raii Cat. Plant. circa Cantab. in Betula.*

yet) if it was accurately viewed, would abundantly manifest itself to be the work of God. But because I have been so long upon the other parts, although less than they deserve, I must therefore content myself with those general hints I have given; which may however serve as specimens of what might have been more largely said about this inferior part of the animated creation.

As to the inanimate part, such as stones, minerals, earth, and such like, that which I have already said in the beginning shall suffice.

B O O K X I.

Practical Inferences from the foregoing SURVEY.

HAVING, in the preceding books, carried my survey as far as I care at present to engage myself, all that remaineth, is to draw some inferences from the foregoing scene of the great Creator's works, and so conclude this part of my intended work.

C H A P. I.

That GOD'S WORKS are GREAT and EXCEL- L E N T.

THE first inference I shall make, shall be by way of confirmation of the text, that the 'works of the Lord are great (a).' And this is

(a) 'Equidem ne laudare quidem satis pro merito possum ejus sapientiam ac potentiam, qui animalia fabricatus est. Nam

necessary to be observed, not against the Atheist only, but all other careless, incurious observers of God's works. Many of our useful labours, and some of our best modern books, shall be condemned with only this note of reproach, that they are about trivial matters (*b*), when in truth they are ingenious and noble discoveries of the works of God. And how often will many own the world in general to be a manifestation of the infinite Creator, but look upon the several parts thereof as only toys and trifles, scarce deserving their regard! But in the foregoing, I may call it, transient view I have given of this lower, and most slighted part of the creation, I have, I hope, abundantly made out, that all the works of the Lord, from the most regarded, admired, and praised, to the meanest and most slighted, are great and glorious works, incomparably contrived, and as admirably made, fitted up, and placed in the world. So far then are any of the works of the Lord, even those esteemed the meanest, from deserving to be disregarded, or contemned by us (*c*), that, on the contrary, they deserve, as shall be shewn in the next chapter, to be sought out, inquired after, and curiously and diligently pried into by us; as I have shewed the word in the text implies.

*' ejusmodi opera non laudibus modo, verum etiam hymnis sunt
' majora, quae priusquam inspexissemus, fieri non posse persua-
' sum habeamus, conspicati vero, falsos nos opinione fuisse com-
' perimus.'* Galen. de usu Part. l. 7. c. 15.

*(b) ' Nam tamen pigere debet lectores, ea intelligere, quemad-
' modum ne naturam quidem piguit ea reipsa efficere.'* Galen. *ibid.* l. 11. fin.

*(c) ' An igitur etiam si quemadmodum natura haec, et ejusmo-
' di, summa ratione ac providentia agere potuit, ita et nos imi-
' tari aliquando possemus? Ego vero existimo multis nostrum
' ne id quidem posse, neque enim artem naturae exponunt: eo
' enim modo omnino eam admirarentur, sin minus eam saltem non
' vituperarent.'* Galen. *ibid.* l. 10. c. 3.

C H A P. II.

That GOD'S WORKS ought to be INQUIRED into, and that such INQUIRIES are commendable.

THE Creator doubtless did not bestow so much curiosity, and exquisite workmanship and skill upon his creatures, to be looked upon with a careless, incurious eye, especially to have them slighted or contemned; but to be admired by the rational part of the world, to magnify his own power, wisdom, and goodness, throughout all the world, and the ages thereof. And therefore we may look upon it as a great error, not to answer those ends of the infinite Creator, but rather to oppose and affront them. On the contrary, my text commends God's works, not only for being great, but also approves of those curious and ingenious inquirers, that seek them out, or pry into them. And the more we pry into, and discover of them, the greater and more glorious we find them to be, the more worthy of, and the more expressly to proclaim their great Creator.

Commendable then are the researches, which many amongst us have, of late years, made into the works of nature, more than hath been done in some ages before. And therefore, when we are asked, *Cui bono?* To what purpose such inquiries, such pains, such expence? The answer is easy, It is to answer the ends for which God bestowed so much art, wisdom, and power about them, as well as given us senses to view and survey them; and an understanding and curiosity to search into them: it is to follow and trace them, when and whither he leads us, that we may see and admire his handy-work ourselves, and set it forth to others, that they may see, admire, and praise it also. I shall then conclude this inference with what Elihu recommends, Job xxxvi.

24. 25. 'Remember that thou magnify his work,
' which men behold. Every man may see it, men
' may behold it afar off.'

C H A P. III.

*That GOD'S WORKS are MANIFEST to all :
whence the Unreasonableness of Infidelity.*

THE concluding words of the preceding chapter suggest a third inference, that the works of God are so visible to all the world, and withal such manifest indications of the being and attributes of the infinite Creator, that they plainly argue the vileness and perverseness of the Atheist, and leave him inexcusable. For it is a sign a man is a wilful, perverse Atheist, that will impute so glorious a work, as the creation is, to any thing, yea, a mere nothing, as chance is, rather than to God (a). It is a sign the man is wilfully blind, that he is under the power of the devil, under the government of prejudice, lust, and passion, not right reason, that will not discern what every one can see, what every man may behold afar off, even the existence and attributes of the Creator from his works. For, as 'there is no speech or language where their voice is not heard, their

(a) Galen having taken notice of the neat distribution of the nerves to the muscles, and other parts of the face, cries out, 'Haec enim fortunae sunt operae ! Caeterum tum omnibus [partibus] immitti, tantosque esse singulos [nervos] magnitudi-
' ne, quanta particulae erat necesse ; haud scio an hominum sit
' sobriorum ad fortunam opificem id revocare. Alioqui quid tan-
' dem erit, quod cum providentia et arte efficitur ? Omnino enim
' hoc ei contrarium esse debet, quod casu ac fortuito sit.' And afterwards, 'Haec quidem atque ejusmodi artis scil. ac sapientiae
' opera esse dicimus, si modo fortunae tribuenda sunt quae sunt
' contraria ; fietque jam quod in proverbiiis—Fluvii sursum
' fluent ; si opera quae nullum habent ornamentum, neque rati-
' onem, neque modum artis esse ; contraria vero fortunae dux
' rimus.' etc. Galen. ubi supra. l. 11. c. 7.

' line is gone out through all the earth, and their
' words to the end of the world:' so all, even the
barbarous nations, that never heard of God, have, from
these his works, inferred the existence of a Deity,
and paid their homages to some deity, although
they have been under great mistakes in their notions
and conclusions about him. But however, this shews
how naturally and universally all mankind agree, in
deducing their belief of a God from the contempla-
tion of his works, or, as even Epicurus himself, in
Tully (b) saith, from ' a notion that nature itself
' hath imprinted upon the minds of men. For, saith
' he, what nation is there, or what kind of men, that
' without any teaching or instructions, have not a
' kind of anticipation, or preconceived notion of a
' Deity?'

An Atheist therefore, if ever there was any such,
may justly be esteemed a monster among rational
beings; a thing hard to be met with in the whole
tribe of mankind; an opposer of all the world (c);
a rebel against his human nature and reason, as well
as against his God.

But above all, monstrous is this, or would be, in
such as have heard of God, who have had the benefit
of the clear gospel-revelation. And still more mon-
strous this would be, in one born and baptized in
the Christian church, that hath studied nature, and
pried farther than others into God's works. For
such an one, if it be possible for such to be, to deny

(b) ' Primum esse Deos, quod in omnium animis,' etc. And
a little after, ' Cum enim non instituto aliquo, aut more, aut lege
' sit opinio constituta, maneatque ad unum omnium firma con-
' sensio, intelligi necesse est, esse Deos, quoniam insitas eorum,
' vel potius innatas cognitiones, habemus. De quo autem om-
' nium natura consentit, id verum esse necesse est. Esse igitur
' Deos confitendum est.' Cicer. de Nat. Deor. l. i. c. 16. 17.

(c) The Atheist in denying a God, doth, as Plutarch saith,
endeavour—' Immobilia movere, et bellum inferre non tantum
' longo tempore, sed et multis hominibus, gentibus, et familiis,
' quas religiosus deorum cultus, quasi divino furore correptas,
' tenuit.' Plutar. de Iside.

the existence, or any of the attributes of God, would be a great argument of the infinite inconvenience of those sins of intemperance, lust, and riot, that hath made the man abandon his reason, his senses, yea, I had almost said his very human nature (*d*), to engage him thus to deny the being of a God.

So also it is much the same monstrous infidelity, at least betrays the same atheistical mind, to deny God's providence, care, and government of the world, or, which is a spawn of the same Epicurean principles, to deny final causes (*e*) in God's works of creation; or with the profane, in Psal. lxxiii. 11. to say, 'How doth God know? and is there knowledge in the Most High?' For, as the witty and eloquent Salvian saith (*f*), 'They that affirm nothing is seen by God, will, in all probability, take away the substance, as well as sight of God.—But what so great madness, saith he, as that when a man doth not deny God to be the Creator of all things, he should deny him to be the Governor of them? Or when he confesseth him to be the Maker, he should say, God neglecteth what he hath so made?'

C H A P. IV.

*That GOD's WORKS ought to excite us to FEAR
and O B E D I E N C E to GOD.*

SINCE the works of creation are all of them so many demonstrations of the infinite wisdom and power of God, they may serve to us as so many

(*d*) See before, note (*b*), p. 402.

(*e*) Galen having substantially refuted the Epicurean principles of Asclepiades, by shewing his ignorance in anatomy and philosophy, and by demonstrating all the causes to be evidently in the works of nature, viz. final, efficient, instrumental, material, and formal causes, concludes thus against his fortuitous atoms, 'Ex quibus intelligi potest, conditorem nostrum in formandis particulis unum hunc sequi scopum, nempe ut quod melius est eligat.' Galen. de usu Part. l. 6. c. 13.

(*f*) De Gubern. Dei. l. 4. p. 124. meo libro; also l. 7. c. 14.

arguments exciting us to the constant fear of God, and to a steady, hearty obedience to all his laws. And thus we may make these works as serviceable to our spiritual interest, as they all are to our life, and temporal interest. For if whenever we see them, we would consider that these are the works of our infinite Lord, and Master, to whom we are to be accountable for all our thoughts, words, and works, and that in these we may see his infinite power and wisdom; this would check us in sinning, and excite us to serve and please him who is above all controul, and who hath our life and whole happiness in his power. After this manner God himself argues with his own 'foolish people, and without understanding, 'who had eyes, and saw not, and had ears, and 'heard not,' Jer. v. 21. 22. 'Fear ye not me? saith 'the Lord: will ye not tremble at my presence, who 'have placed the sand for the bound of the sea, by a 'perpetual decree, that it cannot pass it; and though 'the waves thereof toss themselves, yet can they not 'prevail; though they roar, yet can they not pass 'over it?'

This was an argument that the most ignorant, stupid wretches could not but apprehend; that a Being that had so vast and unruly an element, as the sea, absolutely at his command, ought to be feared and obeyed, and that he ought to be considered as the sovereign Lord of the world, on whom the world's prosperity and happiness did wholly depend; ver. 24. 'Neither say they in their heart, Let us now fear 'the Lord our God, that giveth rain, both the former and the latter in his season: he reserveth unto 'us the appointed weeks of the harvest.'

C H A P. V.

That God's Works ought to excite us to Thankfulness.

AS the demonstrations which God hath given of his infinite power and wisdom should excite

us to fear and obedience ; so I shall shew in this chapter, that the demonstrations which he hath given of his infinite goodness in his works, may excite us to due thankfulness and praise. It appears throughout the foregoing survey, what kindness God hath shewn to his creatures in providing every thing conducing to their life, prosperity, and happiness (a) ; how they are all contrived and made in the best manner, placed in the fittest places of the world for their habitation and comfort ; accoutered in the best manner, and accommodated with every, even all the minutest things that may minister to their health, happiness, office, occasions, and business in the world.

Upon which account, thankfulness and praise is so reasonable, so just a debt to the Creator, that the psalmist calleth upon all the creatures to praise God, in Psalm cxlviii. ' Praise him all his angels, praise him all his host ; sun, moon, stars of light, heavens of heavens, and waters above the heavens.' The reason given for which is, ver. 5. 6. ' For he commanded, and they were created ; he hath also established them for ever and ever ; he hath made a decree which they shall not pass.' And not these celestials alone, but the creatures of the earth and waters too, even the meteors, ' Fire and hail, snow

(a) ' Si pauca quis tibi donasset jugera, accepisse te diceres beneficium : immensa terrarum late patentium spatia negas esse beneficium ? Si pecuniam tibi aliquis donaverit, — beneficium vocabis : tot metalla defodit, tot flumina emisit in aera, super quae decurrunt sola aurum vehentia : argenti, aeris, ferri immane pondus omnibus locis obrutum, cujus investigandi tibi facultatem dedit, — negas te accepisse beneficium ? Si domus tibi donetur, in qua marmoris aliquid resplendeat, etc. Num mediocri munis vocabis ? Ingens tibi domicilium, sine ullo incendii, aut ruinae metu struxit, in quo vides non tenues cruas — sed integras lapidis pretiosissimi moles, etc. negas te ullum munus accepisse ? Et cum ista quae habes magno aestimes, quod est ingrati hominis, nulli debere te judicas ? Unde tibi istum quem trahis spiritum ? Unde istam, per quam ductus vitae tuae disponis atque ordinas, lucem ?' etc. Senec. de Benef. l. 4. c. 6.

‘ and vapours, stormy winds fulfilling his word.
 Yea, the very ‘ mountains and hills, trees, beasts,
 ‘ and all cattle, creeping things, and flying fowl.
 But in a particular manner, all the ranks and orders
 all the ages and sexes of mankind are charged with
 this duty; ‘ Let them praise the name of the Lord,
 ‘ for his name alone is excellent; his glory is above
 ‘ the earth and heavens,’ ver. 13.

And great reason there is we should be excited to
 true and unfeigned thankfulness and praise (b) to this
 our great Benefactor, if we reflect upon what hath
 been shewn in the preceding survey, that the Creator
 hath done for man alone, without any regard to the
 rest of the creatures, which some have held were made
 for the sake of man. Let us but reflect upon the
 excellence and immortality of our soul; the incom-
 parable contrivance, and curious structure of our
 body; and the care and caution taken for the securi-
 ty and happiness of our state, and we shall find, that
 among the whole race of beings, man hath especial
 reason to magnify the Creator's goodness, and with
 suitable ardent affections to be thankful unto him.

(b) ‘ Tempestivum tibi jam fuerit, qui in hisce libris versari
 ‘ considerare, in utram familiam recipi malis, Platonicanne ac
 ‘ Hippocraticam, et aliorum virorum, qui naturae opera miran-
 ‘ tur; an eorum qui ea insectantur, quod non per pedes natura
 ‘ constituit effluere excrementa.’ Of which, having told a story
 of an acquaintance of his, that blamed nature on this account,
 he then goes on: ‘ At vero si de hujusmodi pecudibus plura ver-
 ‘ ba fecero, melioris mentis homines merito mihi forte succen-
 ‘ seant, dicantque me polluere sacrum sermonem, quum ego
 ‘ CONDITORIS nostri verum hymnum compono, existimoque
 ‘ in eo veram esse pietatem,——ut si noverim ipse primus, deus
 ‘ de et aliis exposuerim, quatenam sit ipsius sapientia, quae virtus
 ‘ quae bonitas. Quod enim cultu conveniente exornaverit omnia
 ‘ nullique bona inviderit, id perfectissimae bonitatis specimen
 ‘ esse statuo; et hac quidem ratione ejus bonitas hymnis nobis
 ‘ est celebranda. Hoc autem omne invenisse quo pacto omnia
 ‘ potissimum adornarentur, summae sapientiae est: effecisse autem
 ‘ omnia, quae voluit, virtutis est invictae.’ Galen de usu Part.
 l. 3. c. 10.

CH A P. VI.

That we ought to pay GOD all due HOMAGE, and WORSHIP, particularly that of the LORD's Day.

FOR a conclusion of these lectures, the last thing I shall infer, from the foregoing demonstration of the being and attributes of God, shall be, that we ought to pay God all that homage and worship which his right of creation and dominion entitle him unto, and his great mercies call for from us. And forasmuch as the Creator appointed, from the very creation, one day in seven to his service, it will not therefore be improper to say something upon that subject; and if I insist somewhat particularly and largely thereon, the congruity thereof to the design of these lectures, and the foregoing demonstration, together with the too great inadvertency about, and neglect of this ancient, universal, and most reasonable and necessary duty, will, I hope, plead my excuse. But that I may say no more than is necessary on this point, I shall confine myself to two things; the time God hath taken, and the business then to be performed.

I. The time is one day in seven, and one of the ancientest appointments it is, which God gave to the world. For, as soon as God had finished his six days works of creation, it is said, Gen. ii. 2. 3. He rested on the seventh day from all his work which he had made. And God blessed the seventh day, and sanctified it, because that in it he had rested from all his work.' This sanctification (a), and blessing the seventh day, was setting it apart,

(a) 'קדש' *sibus divinis accommodavit, a communi et profano usu segregavit, in usum sacrum ad cultum Dei destinavit.* Arch. Concord. p. 1336. 'Destinari ad aliquid, sacrari,' etc. *extorf. in verbo.*

as a day of distinction from the rest of the week-days, and appropriating it to holy uses and purposes, namely, the commemoration of that great work of the creation, and paying homage and worship to that infinite Being, who was the effector of it.

This day, thus consecrated from the beginning, for the celebration of the *τὴν κόσμου γενέσιν*, the 'world's birth-day,' as Philo calls it, was probably, in some measure, forgotten in the following wicked ages, which God complains of, Gen. vi. 5. and so after the flood likewise. But after the return out of Egypt, when God settled the Jewish polity, he was pleased to renew this day, and to establish it for a perpetual standing law. And accordingly it was observed down to our blessed Saviour's time, countenanced, and strictly observed, by our great Lord and Master himself, and his apostles and disciples, in and after his time; and although, for good reasons, the day was changed by them, yet a seventh day hath been constantly observed in all ages of Christianity down to our present time.

Thus we have a day appointed by God himself, and observed throughout all ages, except some few, perhaps, which deserve not to be brought into example.

And a wise designation of time this is, well becoming the divine care and precaution; serving for the recruiting our bodies, and dispatching our affairs, and at the same time to keep up a spiritual temper of mind. For, by allowing six days to labour, the poor hath time to earn his bread, the man of business time to dispatch his affairs, and every man time for the work of his respective calling. But had there been more, or all our time allotted to labour and business, and none to rest and recruit, our bodies and spirits would have been too much fatigued and wasted, and our minds have been too long engaged about worldly matters, so as to have forgotten divine things. But the infinitely wise Ruler of the world

having taken the seventh part of our time to his own service, hath prevented these inconveniencies, hath given a relaxation to ourselves; and ease and refreshment to our wearied beasts, to poor fatigued slaves, and such as are under the bondage of avaricious, cruel masters. And this is one reason Moses gives of the reservation and rest on the seventh day, Deut. v. 13. 14. 15. 'Six days shalt thou labour, and do all thy work; but the seventh is the sabbath of the Lord thy God; in it thou shalt not do any work, thou, nor thy children, servants, cattle, or stranger, that thy man-servant and maid-servant may rest as well as thou. And remember that thou wast a servant, etc. therefore the Lord thy God commanded thee to keep the sabbath-day.' That carnal, greedy people, so bent upon gain, without such a precept, would have scarce favoured their own bodies, much less have had mercy upon their poor bondsmen and beasts; but by this wise provision, this great burden was taken off. But on the other hand, as a longer liberty would too much have robbed the master's time, and bred idleness, so by this wise provision, of only one day of rest, to six of labour, that inconveniency was also prevented.

Thus the wise Governor of the world hath taken care for the dispatch of business. But then as too long engagement about worldly matters would take off mens minds from God and divine matters, so by this reservation of every seventh day, that great inconvenience is prevented also; all being then bound to worship their great Lord and Master, to pay their homages and acknowledgments to their infinitely kind Benefactor; and, in a word, to exercise themselves in divine, religious business, and so keep up that spiritual temper of mind, that a perpetual, or too long application to the world would destroy.

This, as it was a good reason for the order of a sabbath to the Jews; so is as good a reason for our

Saviour's continuance of the like time in the Christian church.

And a law this is, becoming the infinitely wise Creator and Conservator of the world, a law, not only of great use to the perpetuating the remembrance of those greatest of God's mercies then commemorated, but also exactly adapted to the life, occasions, and state of man; of man living in this, and a-kind to another world: a law well calculated to the dispatch of our affairs, without hurting our bodies or minds. And since the law is so wise and good, we have great reason then to practise carefully the duties incumbent upon us; which will fall under the consideration of the

II. Thing I proposed, the business of the day, which God hath reserved to himself. And there are two things enjoined in the commandment, a cessation from labour and worldly business; and that we remember to keep the day holy.

First, There must be a cessation from worldly business, or a rest from labour, as the word *sabbath* (*b*) signifies. 'Six days thou shalt do all thy work, but the seventh is the sabbath of the Lord thy God, (not thy day but his), in which neither thou, nor any belonging to thee, shall do any work.' In which injunction it is observable, how express and particular this commandment is, more than others, in ordering all sorts of persons to cease from work.

Secondly, We must remember to keep the day holy. Which remembrance is another thing also in this, more than in the other commandments, and implies,

1st, That there is great danger of our forgetting, neglecting, or being hindered from keeping the day holy, either by the infirmity and carnality of our own nature, or from the avocations of the world.

2dly, That the keeping it holy is a duty of more

(שבת) *Cessatio*, requires.

than ordinary consequence and necessity. And of greatest consequence this is,

1. To perpetuate the remembrance of those grand works of God commemorated on that day; in the first ages of the world, the creation; in the middle ages, the creation and delivery from Egypt; and under Christianity, the creation and redemption by Christ. Which mercies, without such frequent occasions, would be ready to be forgotten, or disregarded, in so long a track of time, as the world hath already stood, and may, by God's mercy, still stand.

2. To keep up a spiritual temper of mind, by those frequent weekly exercises of religion, as hath been already mentioned.

3. To procure God's blessing upon the labours and business of our six days, which we can never expect should be prosperous, if we are negligent of God's time. For, how can we expect God's blessing, upon a week so ill begun, with a neglect, or abuse of God's first day? And therefore if we become unprosperous in the world; if losses, troubles or dangers befall us, let us reflect how we have spent the Lord's day; whether we have not wholly neglected it, or abused it in riot, or made it a day for taking journies, for more private business, and less scandalous labour, as the custom of too many is.

Thus having shewn what reason there is to remember to keep holy the day dedicated to God, I shall consider how we are to keep it holy, and so conclude. Now, the way to keep it holy, is not by bare resting from work; for that, as a father saith, is 'Sabbatum boum et asinorum, a sabbath of beasts:' but holy acts are the proper business of a holy day, celebrated by rational beings. Among all which, the grand, principal, and most universally practised, is the public worship of God, the assembling at the public place of his worship, to pay, with our fellow-creatures, our homages, thanks, and praises to the infinite Creator and Redeemer of the world. This,

as it is the most reasonable service, and proper business for this day, so is what hath been the practice of all ages. It was as early as Cain and Abel's days, Gen. iv. 3. what was practised by religious persons in the following ages, till the giving of the law; and at the giving of that, God was pleased to order places, and his particular worship, as well as the seventh day. The tabernacle and temple were appointed by God's express command; besides which, there were synagogues all over the nation; so that in our Saviour's time, every great town, or village, had one, or more in it, and Jerusalem 460, or more (c).

The worship of these places, our blessed Saviour was a constant and diligent frequenter of. It is said, 'He went about all the cities and villages, teaching in their synagogues, and preaching, and healing,' etc. Matth. ix. 35. And St Luke reporteth it as his constant custom and practice, Luke iv. 16. 'And as his custom was, he went into the synagogue on the sabbath day.'

Having thus mentioned the practice of Christ, it is not necessary I should say much of the practice of his apostles, and the following purer ages of Christianity, who, in short, as their duty was, diligently followed their great Master's example. 'They did not think it enough to read and pray, and praise God at home, but made conscience of appearing in the public assemblies, from which nothing but sickness and absolute necessity did detain them; and if sick, or in prison, or under banishment, nothing troubled them more, than that they could not come to church, and join their devotions to the common services. If persecution at any time forced them to keep a little close; yet no sooner was there the least mitigation, but they presently returned to their open duty, and publicly met all together. No trivial pretences, no light excuses,

(c) See Lightfoot's Works, vol. 2. p. 35, and 646.

' were then admitted for any one's absence from the congregation, but according to the merit of the cause, ' severe censures were passed upon them,' etc. to express it in the words of one of our best antiquaries (d).

The public worship of God then is not a matter of indifference, which men have in their own power to do, or omit, as they please; neither is it enough to read, pray, or praise God at home, unless some inevitable necessity hindereth; because the appearing in God's house, on his day, is an act of homage and fealty, due to the Creator, a right of sovereignty we pay him. And the with-holding those rights and dues from God is a kind of rejecting God, a disowning his sovereignty, and a withdrawing our obedience and service. And this was the very reason why the profanation of the sabbath was punished with death among the Jews, the sabbath being a sign, or badge of the God they owned and worshipped (e).

(d) Dr Cave's *Primitive Christianity*, p. 1. cap. 7.

(e) At this day it is customary for servants to wear the livery of their masters, and others to bear badges of their order, profession, servility, etc. So in former ages, and divers countries, it was usual to bear badges, marks, and signs on divers occasions. In Ezek. ix. 4. ' A mark was to be set on the forehead of those ' that lamented the abominations of the city.' The like was to be done upon them in Rev. vii. 3. and ix. 4. So the worshippers of the beast, Rev. xiii. 16. were to receive a *Χάραγμα*, ' A mark ' in the right hand, on their foreheads.' Those *Χάραγματα*, *Σφραγίδες*, Badges, etc. were very common. Soldiers and slaves bare them in their arms or foreheads; such as were matriculated in the *heteriae*, or companies, bare the badge or mark of their company; and whoever listed himself into the society of any of the several gods, received a *Χάραγμα*, or a mark in his body, (commonly made with red-hot needles, or some burning in the flesh), of the God he had listed himself under. And after Christianity was planted, the Christians had also their sign of the cross. And not only marks in their flesh, badges on their clothes, etc. were usual; but also the dedication of days to their imaginary deities. Not to speak of their festivals, etc. the days of the week were all dedicated to some of their deities. Among the Romans, Sunday and Monday, to the Sun and Moon; Tuesday to Mars; Wednesday to Mercury, etc. So our Saxon ancestors did the same; Sunday and Monday, as the Romans did to the Sun and Moon; Tuesday to *Tuysco*; Wednesday to *Woden*;

Thus Exod. xxxi. 13. 'My sabbaths ye shall keep; 'for it is a sign between me and you, throughout 'your generations; that ye may know that I am the 'LORD, that doth sanctify you;' or, as the original may be rendered, 'A sign to acknowledge that I 'JEHOVAH am your Sanctifier, or, your GOD:' for, as our learned Mede observes, 'To be the Sanctifier 'of a people, and to be their GOD, is all one.' So likewise very expressly in Ezek. xx. 20. 'Hallow my 'sabbaths, and they shall be a sign between me and 'you, that ye may know that I am the LORD your 'GOD;' or rather as before, 'to acknowledge that I 'JEHOVAH am your GOD.'

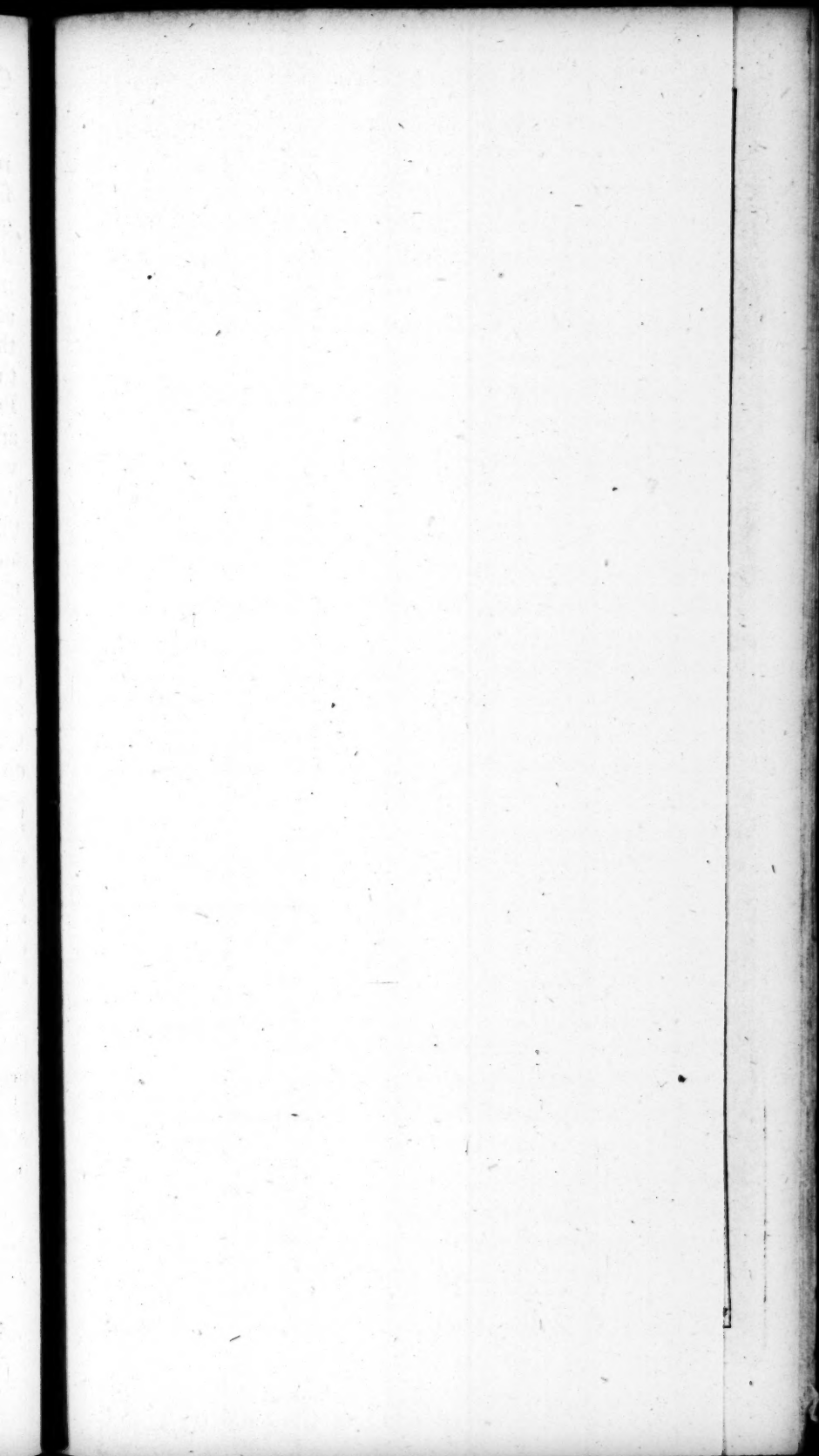
The sabbath being thus a sign, a mark, or badge, to acknowledge God to be their God, it follows, that a neglect or contempt of that day redounded to God; to slight that, was slighting God; to profane that, was to affront God; for the punishment of which, what more equitable penalty than death! And although under Christianity, the punishment is not made capital, yet have we no less reason for the strict observance of this holy day than the Jews, but rather greater reasons. For the God we worship, is the same: if after the six days labour, he was, by the seventh, owned to be God, the Creator; no less is he by our Christian Lord's day: if by the celebration of the sabbath, the remembrance of their deliverance from the Egyptian bondage was kept up, and God acknowledged to be the effector thereof; we Christians have a greater deliverance; we own our deliverance from sin and Satan, wrought by a greater Redeemer than Moses, even the blessed Jesus, whose resurrection, and the completion of our redemption thereby, was performed on the Christian Lord's day.

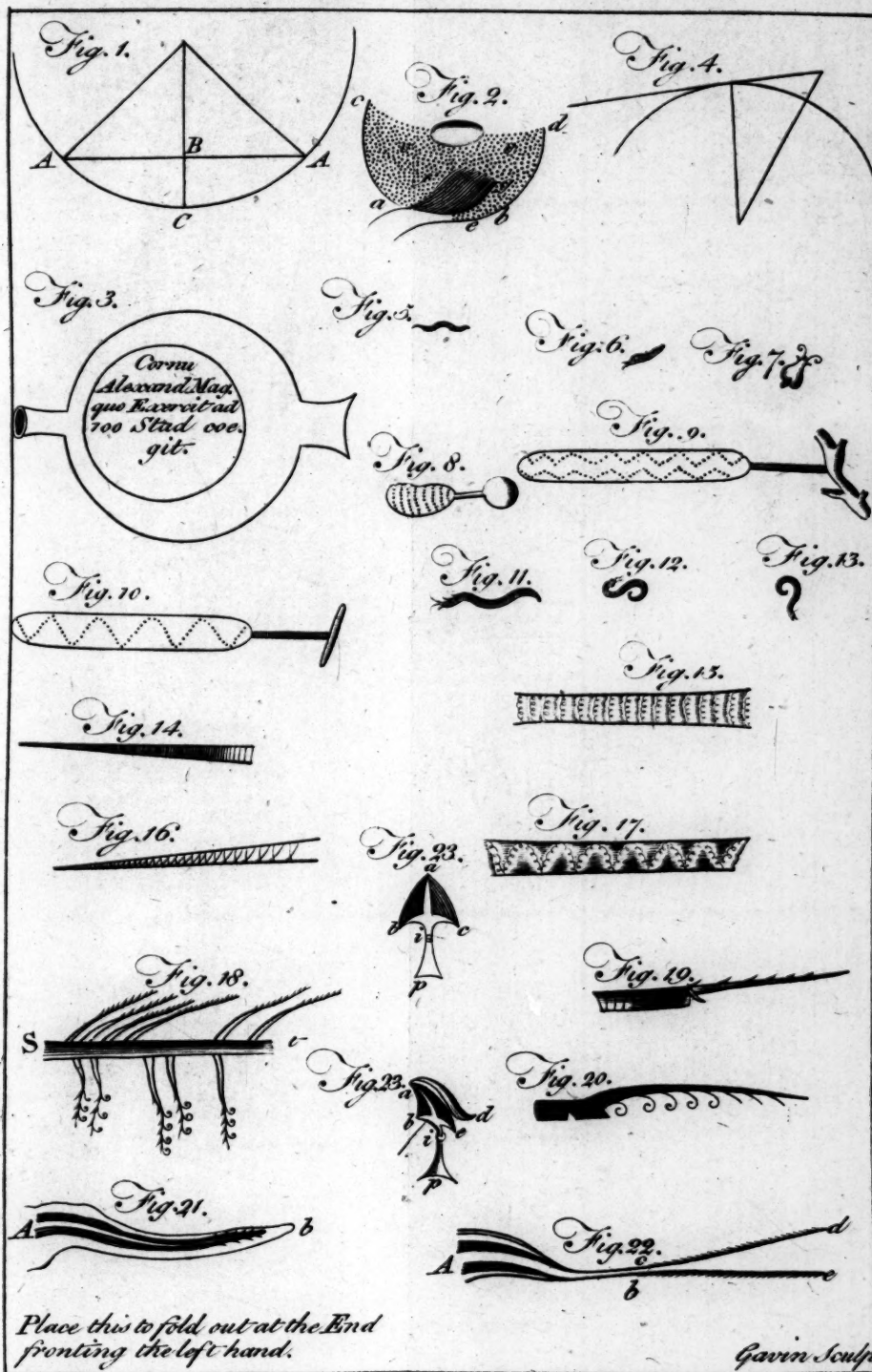
Thursday to Thoor; Friday to Friga; and Saturday to Seater: an account of which deities, with the figures under which they were worshipped, may be met with in our learned Verstegan, chap. 3. p. 68.

And now, to sum up, and conclude these inferences, and so put an end to this part of my survey: since it appears, that the works of the Lord are so great, so wisely contrived, so accurately made, as to deserve to be inquired into; since they are also so manifest demonstrations of the Creator's being and attributes, that all the world is sensible thereof, to the great reproach of atheism: what remaineth, but that we fear and obey so great and tremendous a Being! that we be truly thankful for, and magnify and praise his infinite mercy, manifested to us in his works! And forasmuch as he hath appointed a day on purpose, from the beginning, for these services, that we may weekly meet together, commemorate and celebrate the great work of creation; that we may pay our acts of devotion, worship, homage, and fealty to him; and since this is a wise and excellent distribution of our time, what should we do, but conscientiously and faithfully pay God these his rights and dues! and as carefully and diligently manage God's time, and discharge his business then, as we do our own upon six days; particularly that with the pious psalmist, 'we love the habitation of God's house, and the place where his honour dwelleth;' and therefore take up his good resolution in Psal. v. 7. with which I shall conclude; 'But as for me I will come into thine house in the multitude of thy mercy, and in thy fear will I worship towards thy holy temple.'

Now, to the same infinite God, the omnipotent Creator and Preserver of the world, the most gracious Redeemer, Sanctifier, and Inspirer of mankind, be all honour, praise, and thanks, now and for ever.
AMEN.

THE END.





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